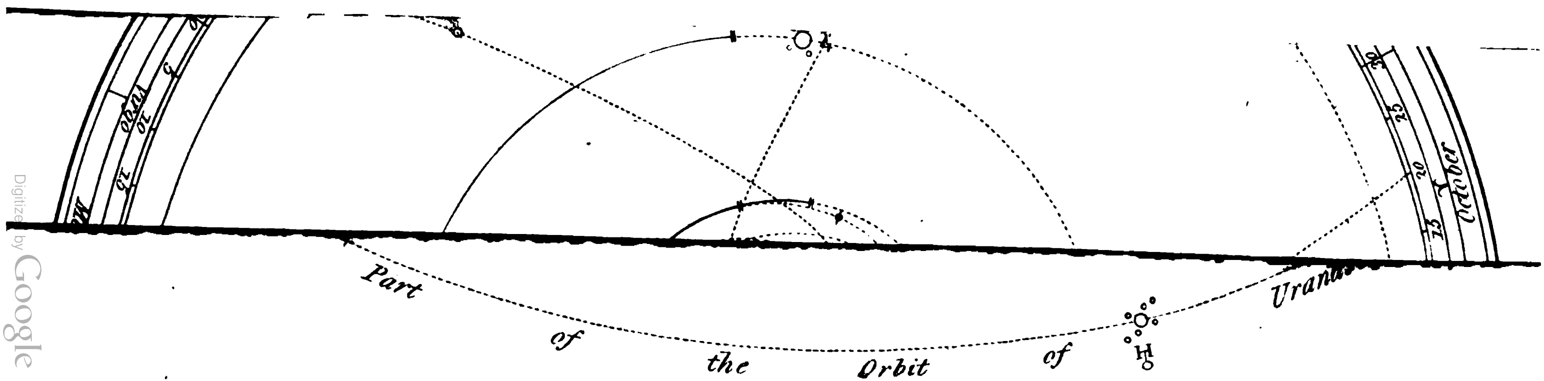
Part of the Orbit of Uranus
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Virgo
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A KEY

TO THE

KNOWLEDGE OF NATURE;

OR

AN EXPOSITION

OF THE

MECHANICAL, CHEMICAL, AND PHYSICAL LAWS

Imposed on Matter by the Wisdom of the Almighty:

COMPRISING

A BRIEF SYSTEM

OF

NATURAL PHILOSOPHY AND CHEMISTRY,

ALSO

A NEW SYSTEM OF PHYSIOLOGY,

WHEREIN ALL THE PHENOMENA OF NATURE ARE EXPLAINED ON ELECTRO-CHEMICAL PRINCIPLES.

BY

THE REV. R. TAYLOR.

"AND GOD SAID, LET THERE BE LIGHT: AND THERE WAS LIGHT."

LONDON:
PUBLISHED BY
BALDWIN, CRADOCK, AND JOY,
PATERNOSTER-ROW;
AND W. ROBINSON, STOCKTON.
1825.

W. Robinson, Printer, Stockton.

PREFACE.

THE original design of the author of the following pages was to present a mere abstract of the modern discoveries in Natural Philosophy, Chemistry, and Physiology, in the most popular form; but in attempting such an abstract, he was unavoidably led to a minute investigation of all the new discoveries of Sir H. Davy in ELECTRO-CHEMISTRY. And, these, together with what is stated in the note at page 208, forcibly impressed on his mind the very obvious and easy solution, which the doctrine of the electro-chemical principles offers to all the difficulties hitherto attending an explanation of the grand operations continually going on in the *material* Universe. Instead, therefore, of giving a mere outline of the discoveries and hypotheses of others, he was irresistibly led to use those discoveries as the foundation and support of what, when perfect, he conceives will be a complete system of NATURE, no less remarkable for its simplicity than its grandeur!

As he traced the various branches of his system, the elucidation of each particular part threw a light over the whole; so that, where conjecture was, at first, the utmost limits at which he could arrive, he afterwards attained to demonstrative inductions, and he has consequently had some sections to re-write many times. And as some parts were printed before others were traced to their present length, perhaps, there may, even yet, be passages, which, if the author had them now to correct for the press, would appear under an improved form. However, he does not know any particular part which he would very materially alter; though, perhaps, he could point out some that might be replaced with more important matter, and others that require a little more elucidation. But such is the vast design, that, had his efforts been crowned with the most complete success, they still must have been regarded in the light of only a mere attempt.

With respect to the first eight chapters, or the mechanical part, he has nothing particular to remark; except that, to separate, as much as possible, the mechanical from the chemical seems to possess some advantages: for, by this means, the system of chemistry is rendered a great deal more concise, simple, and intelligible. For the theory of Chemical Affinity, or Electro-Chemistry, the author is indebted to the splendid discoveries of Sir H. Davy. He is not aware that he has met with any direct hint, in any author respecting the theory of gravitation and planetary motion; but he conceives it to be a legitimate induction from his premises, and strongly corroborated by the passage quoted at page 355. The theory of Light and Heat seems a plain inference from that of planetary motion, or rather from the same premises; but, perhaps, men of more sober, scientific demonstration may denounce it as a mere fancy,—it may be so:—but the extract from Sir H. Davy, will shew that the theory of heat is not entirely new. Electro-Magnetism and Crystallization may, perhaps, be considered as partly akin to the theory of Light; but in these cases the author wishes rather to point out the field of future discoveries, than to pretend that he has exactly developed the principles of these sciences:—yet, he flatters himself, that the whole carries with it an air of probability, sufficient to shew that Nature throughout all her operations is equally simple, and works by the same means, only varied a little according to circumstances.

The theory of Geology is founded on Sir W. Herschel's observations on *nebulæ*, and the known laws of the electric energies as displayed in the mechanical properties of caloric. Though the author has, since it was planned, frequently met with hints of its principles, as in Bakewell's Introduction to Geology, also in Knight's New Theory of the Earth; yet, he is not aware, that it was ever before attempted to supply the interval between the observations on nebulæ and the present phenomena in the stratification of the earth's shell, or, thence to account for the many revolutions to which the surface of our planet has been subject. The principles, on which the theory of Meteorology are founded, are so obvious, that it is surprising

they were never pointed out before. With respect to the theories of Vegetation and Animalization the facts and experiments must bear them out; though Reece lays down the electro-principles of muscular motion in his Introduction to the Medical Guide.

Had the author, in the body of the work, mentioned all the books to which he has had recourse, and distinctly assigned to each author his right, the pages must have been clogged with names and references. Besides, as he has been for some time collecting what suited his purpose from nearly all the Scientific Journals of the present day, he could not, now, if he would, assign to each his own. But though he enriched his note-book with detached passages from a multitude of sources, yet there are some authors whose works he has used in a less reserved manner. Among these must be mentioned, in the first place, Parkes' Chemical Catechism, Outlines of the Geology of England and Wales by Conybeare and Phillips, also Phillips' Introduction to Mineralogy. On Astronomy and the other sciences of Natural Philosophy, were consulted Squire's Grammar of Astronomy, Blair's Grammar of Natural and Experimental Philosophy, Playfair's Outlines of Natural Philosophy, Walker's Experimental Philosophy, Imison's Elements of Science and Art, and Joyce, also, the Encyclopædia Perthensis, and Hall's Dictionary of the Arts and Sciences. On Electricity, and Chemistry, Sir H. Davy's Elements, Thompson's System of Chemistry, and the elegant little work called Conversations on Chemistry were referred to, with many others which the author met with in the Library of the Philosophical Society of Newcastle-upon-Tyne. Besides some of these popular works, he used on Magnetism, Barlow's Magnetic Attractions, and the Encyclopædia Metropolitana. Polehampton's Gallery of Nature and Art has also been a fertile source of information. On Vegetable Economy he has been chiefly indebted to the writers on Chemistry; and for the Mechanism of the Human Frame and Animal Economy, Hooper's Anatomy, Paley's Theology, and some other more popular works have been used. On the science of Geology, he has consulted Bakewell, Knight's New Theory of the Earth, Macculloch, Buckland, Humboldt, with

some of the decided Huttonians and Wernerians, and the Transactions of the Geological Societies. Besides these, are gleanings from various sources, some of which are mentioned in the course of the work.

The author's aim, as it respects the arrangement, was to attempt one regular system of the laws and operations of Nature; and therefore, the sciences are disposed accordingly. But by these means they are made to elucidate each other; and the reader is thus led on by easy steps to a knowledge of the foundation of all the Arts and Sciences, while he perhaps imagined himself only in the pursuit of the mere laws of Nature. Hence the author has greatly mistaken his intentions if he has not very much smoothed the path, and shortened the distance to a perfect knowledge of the whole circle of Science and Art.

But besides the elucidation of Science and the display of Nature, he had another object in view; viz. to shew that there is nothing in the material world which can possibly favour the doctrine of Materialism. "In all cases," says Paley, "wherein the mind feels itself in danger of being confounded by variety, it is sure to rest upon a few strong points, or perhaps upon a single instance." That luminous author fixed upon some curious contrivances in the human frame; the author, in the present instance, takes his stand in the wide gap between Matter, Life, and Mind; and supposes that he has shewn, even while he was only engaged with the material world, how impossible it is to explain the operations of Life by the mere energies of matter,—much less those of mind: and that, whatever the Materialist, Atheist, or self-stiled Deist, advances to keep himself in countenance when he would decry Revealed Religion, there is nothing in the material world which he can lawfully advance.

Hart, Durham,
March 1st, 1825.

ERRATA.

Page 26	line 42	*for* to *read* on
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304	17	*for* Argenteria *read* Argentiera
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326	26	*for* tomlac *read* tombac
328	29	*for* pure oxygen *read* puce oxide
329	6	*for* rauciness *read* raciness
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399	2	*for* Tarpean *read* Tarpeian
490	19	*for* Messena *read* Messina
556	38	*for* labratory *read* laboratory
568	41	*for* have *read* has
588	30	*for* libricates *read* lubricates

A
KEY
TO THE
KNOWLEDGE OF NATURE.

CHAP. I.

The Solar System.

I. ASTRONOMY.

1. ASTRONOMY. 2. THE OBJECTS OF ASTRONOMY. 3. THE SOLAR SYSTEM DEFINED. 4. THE ECLIPTIC AND ZODIAC. 5. REAL AND APPARENT MOTION OF THE SUN AND INFERIOR PLANETS. 6. REAL AND APPARENT MOTION OF THE SUPERIOR PLANETS. 7. THE SECONDARY PLANETS OR SATELLITES.

ASTRONOMY is the most sublime and delightful of all the sciences. It raises the mind of man from calculating his steps upon the surface of the planet he inhabits, to ascertain the track, measure the distance, and grasp the bulk of those he sees wandering through the skies. Instead of merely rejoicing in the cheering influence of the sun that warms and invigorates his frame, Astronomy enables him to enjoy a perpetual mental feast, in contemplating the many worlds the sun dispenses life to besides his own. In the absence of the solar ray, he sees a sun in every fixed star, calculates the number of worlds each one enlivens, and sympathizes with their inhabitants.

But what are the few stars he sees with the naked eye, compared with those which the piercing sweep of the telescope detects in the fathomless abyss of the heavens! In this illimitable space, he is overwhelmed with the vast idea of the plenitude of Creation. His mind either recoils upon itself, stunned with the conviction of its own impotency, or seeks for rest

upon the invigorating contemplation of the Wisdom, Power, and Goodness of the GREAT CREATOR.

Hence, though the science of Astronomy sets out with such lofty pretensions, it has, of all the sciences, the greatest tendency to humble the proud and arrogating spirit of man. For it teaches him, that with all his ingenuity and collected wisdom, —and even with his boasted telescope, he in reality has no more just claim to a knowledge of the universe, than an illiterate person, who had never been beyond the walls of a dungeon, or had seen more of what was passing on the face of the earth than he could perceive through his grated window, would have to what we call a knowledge of the world.

Yet, however small the portion of the universe may be with which we can possibly become acquainted, it is to Astronomy we owe the knowledge of that portion; and from what we know of it, we presume to form conjectures concerning the rest. To Astronomy we are indebted for an acquaintance with the mechanism and laws of our planetary system; with the nature and cause of day and night; the vicissitudes of the seasons; the eclipses of the sun and moon, with the changes of the latter; and with several other natural phenomena, of the real cause of which the ancients were totally ignorant. Indeed, some of these natural occurrences, as an eclipse or the advance of a comet, frequently filled them with the most dreadful apprehensions of impending calamities. Astronomy has delivered us from such vain fears. And, besides its extending the sphere of human knowledge, and giving us nobler conceptions of the Deity from a contemplation of the magnificence of his works, it has taught us to brave the trackless ocean; to make the productions of every climate our own; and to spread all the conveniences and luxuries of life, as well as knowledge human and divine, over the face of the whole earth.

2. THE OBJECTS OF ASTRONOMY.

THE earth, moon, sun, stars and comets are properly the objects of the science of Astronomy. The stars are of two kinds: *planets* and *fixed stars*. The latter never change their situations in the heavens; but the former are continually in motion; hence, they are called *planets* or *wanderers*. They may be seen travelling, like the moon but not so rapidly, among the fixed stars towards the east. They are of the same nature

as the earth; and like the earth, encircle the sun. These planets, together with the earth which is also a planet, and the sun and moon, form what we call our Solar System.

In common language we would say, that the bodies which compose our Solar System, are at an immense distance; but in the language of Astronomy, or compared with the fixed stars, they are in our immediate neighbourhood. It is true, the distance of all of them, except the moon, is always spoken of in millions of miles; but, the distance between the solar system itself and the fixed stars, even the nearest of them, is always represented in millions of millions of miles. And the fixed stars are, perhaps, all at as great a distance from each other. Consequently, our solar system is completely detached from the fixed stars; so that, in the science of Astronomy we have no more to do with them, than merely to guess at their immense distances; or use them as marks to point out the situations and tracks of the planets.

The planets are divided into two classes, *primary* and *secondary*. The primary planets move round the sun as a centre. They are seven in number; and their names, as well as the characters by which they are often represented, are as follows:—
Mercury ☿. Venus ♀. Terra, or the Earth ⊕. Mars ♂. Jupiter ♃. Saturn ♄. Uranus ♅.

Between Mars and Jupiter have lately been discovered by the assistance of the telescope, four planetary bodies; which, on account of their diminutiveness, are not deemed worthy of being classed among the planets. They are consequently distinguished by the term *Asteroids*. Their names are Vesta ⚶. Juno ⚵. Ceres ⚳. and Pallas ⚴.

The *secondary* planets, called also *Satellites*, move round the primary planets as their centres, nearly in the same manner as the primaries encircle the sun. They are eighteen in number; but only one is visible to the naked eye; viz. the moon which accompanies the earth. Jupiter has four satellites, Saturn seven, and Uranus six.

Before we attempt to explain the motions of the planets, it may be necessary to remark, that the utmost extent of space, including the works of the Almighty, cannot be reached by the imagination of man; much less can it be defined by numbers: so that, a million of miles with Him, are as indifferent as a hair's breadth with us; and the number of stars in the universe, though we cannot see more than a thousand at once with the naked eye,

would be, were the whole visible, no less difficult to count, than the grains of sand in the whole earth.

In the language of Astronomy the terms *above* and *below*, have only reference to ourselves as standing upon the earth. We always say the earth is beneath our feet; but as the earth and not the heavens, as will hereafter be shewn, turns round, it is evident, that if our heads at *noon* point to any particular place in the skies, at *midnight* our feet will point to that place; consequently, with respect to it, we might be said to walk with our feet upwards.

Although the fixed stars seem to be placed in the firmament at an equal distance with the moon and planets, they are in reality, as we have already stated, farther from us by millions of millions of miles; and all of them perhaps at as great a distance from each other as from us, stretching on, one beyond another, farther than the imagination can follow them. This optical deception, in their appearing all studded round the inside of a large basin turned over our heads, so as to form the lofty vault of the skies, is owing to our viewing them through the atmosphere; and seeing, on account of their great distance, only a very small portion of the light which they emit.

3. THE SOLAR SYSTEM DEFINED.

The Sun ☉, for the present, we shall call a globe of light and heat. This globe is so large, that to measure its diameter would take almost 900,000 miles, or nearly 3¼ times the distance of the moon; so that, in magnitude, it is almost a million and a half times larger than the globe we inhabit. This stupendous mass is suspended by the hand of the Almighty upon Nothing.

Conceive then this body placed in the centre; and sending forth light and heat to a distance all around of at least 2,000 millions of miles. Within the field of this light and heat are placed the planets, at various distances from the sun one beyond another nearly in the same plane; or so, that a line drawn from the solar centre would almost touch all their paths.

These planets or worlds are all encircling the sun as a centre with a velocity that is almost inconceivable: some of them moving nearly three hundred times swifter than a cannon-ball. But on account of their various distances from the sun, the courses which they travel are of different lengths; and consequently

a different space of time is requisite wherein to make a complete revolution. Their motion is from west to east, or contrary to the apparent motion of the sun. Their diameters, their distances from the sun, their hourly progress, and the periodical times of their revolutions, are, in round numbers, as follows.

Diameter in Miles.		Dis. from Sun in millions of Miles.	Hourly Progress in miles.	Time of Revolution.
Mercury	3,130	36	109,442	87 Days. 23 Hrs.
Venus	7,700	68	80,062	224 — 16 —
Earth	7,914	95	68,092	1 Year.
Mars	4,200	144	55,162	1 — 321 Days.
Asteroids. Vesta		225	44,202	3 Yrs. 240 —
Juno		253	41,170	4 — 130 —
Ceres	162	262	40,932	4 — 220 —
Pallas	147	262	40,930	4 — 220 —
Jupiter	91,000	494	29,866	11 — 314 —
Saturn	77,680	906	22,050	29 — 167 —
Uranus	34,170	1,822	15,546	84 — 7 —

For a more exact statement, see table at the end of Chap. IV.

On account of the immense distances of the planets from the sun, it is impossible to give any just idea of those distances, and their proportional magnitudes in the same figure drawn upon paper. Fig. 1. is a representation of the Solar System; but in it even the sun is only a mere point. And indeed, if we had a figure of a mile diameter, it would only allow the sun's diameter to be about fifteen inches; and the earth's not more than one seventh part of an inch. Hence most of the figures, found in books of Astronomy, intended to illustrate these proportions, serve in general to perplex rather than assist the understanding.

The planets between the earth and sun, Venus and Mercury, are called the *inferior* planets; and those beyond the earth, as Mars, Jupiter, Saturn, and Uranus are the *superior* planets.

4. THE ECLIPTIC AND ZODIAC.

SUPPOSE a line, as that called the line of direction, Fig. 1. to pass through the centres of the earth and sun; and to con-

tinue indefinitely, in each direction, among the fixed stars. This line, being carried all round, as the earth travels round the sun, would describe a circular plane, as in the figure. This imagiuary plane, is called the *plane of the earth's orbit;* and the place, where the extended line passes through or cuts the fixed stars all round the sky, is called the *Ecliptic.* The plane of the earth's orbit and the plane of the ecliptic are the same.

The Zodiac.—Each of the planets likewise has a plane of its orbit; but these planes do not coincide as they are represented to do in Fig. 1. The lines passing from the sun's centre through the centre of each planet, will be either on one side or the other of the ecliptic. And, as the planes all make different angles with the plane of the earth's orbit, so no two can be in the same plane. The planets, therefore, as may be seen by Fig. 2. will sometimes be at one side of the ecliptic, sometimes upon or crossing it, and sometimes at the other side. They will dilate the line of the ecliptic on each side into a zone: Mercury going the widest and the moon the next. This zone is called the *Zodiac.* Though Mercury never goes wider than seven degrees on each side of the ecliptic; the zodiac is nevertheless allowed in Astronomy to extend to eight degrees, making the whole zone all round the heavens sixteen degrees. However some of the Asteroids, especially Pallas, have a much wider range.

For the sake of convenience the Ecliptic or Zodiac is divided into twelve parts called signs; and as every circle is divided into 360 degrees, each degree into 60 miles or minutes, and each minute into 60 seconds; so each sign contains 30 degrees, as represented in the Solar System, Fig. 1. The names and characters of the signs are as follows: Aries ♈. Taurus ♉. Gemini ♊. Cancer ♋. Leo ♌. Virgo ♍. Libra ♎. Scorpio ♏. Sagittarius ♐. Capricornus ♑. Aquarius ♒. Pisces ♓. The former six are called *northern* signs, and the latter *southern.*

Nodes.—Each planet in every revolution passes through the plane of the earth's orbit, or crosses the ecliptic *twice.* The places where a planet crosses the ecliptic are called its nodes. The one where it crosses northwards is called the *ascending* node; and the other, where it recrosses to the south, the *descending* node. A line joining the two nodes is called the line of the nodes. When a planet has passed the ascending node, it inclines, for one quarter of its revolution, northward.

it is then said to be in northern latitude; and the distance is calculated in degrees from the ecliptic. It then recedes through another quarter of its revolution; at the expiration of which, it passes its descending node; and is in southern latitude during the remaining half of its revolution.

As Fig. 1. represents the plane of the ecliptic, and Fig. 2. a vertical section of it, *above* the surface of the paper in Fig. 1. is northern latitude; and this half of each planet's orbit is represented by a black line; and *below* the surface is southern latitude, represented by a dotted line. But in Fig. 2. the side of the line marked "The Ecliptic" towards the upper part of the page, but upon the surface of the paper, is northern latitude; while the lower side, upon the surface of the paper, is southern latitude. Where the dotted line ends Fig. 1. and the black line begins is the ascending node; and where the black line terminates and the dotted line commences is the descending node. The planets move in the order of the signs; that is, from Aries, to Taurus, Gemini, &c.

Were all the planets at any time in a line with the earth at one side of the sun, that is, all in conjunction with the earth; it would be, omitting Uranus, 280,000 years before they would be again in a similar situation: consequently, we may infer that all of them were never at the same time in conjunction with the earth; nor perhaps ever will be. We shall therefore always find them dispersed in different parts of the zodiac; and as they, as well as the earth, are continually in motion, no general rule for finding them can be given. Their exact positions, every day in the year, are stated in the *Nautical Almanack*, also in White's *Ephemeris:* which publications contain every information of this kind, necessary for the practical astronomer. The situations of the seven primary planets are given in Fig. 1. which, in this respect, represents the solar system at the commencement of the spring quarter, when the sun enters Aries on the 21st of March 1824.

5. REAL AND APPARENT MOTION OF THE SUN AND INFERIOR PLANETS.

To derive any great advantage from the assistance of Fig. 1. the reader should imagine straight lines from the earth, through each of the planets to the ecliptic: where these lines cut the ecliptic is the place where he will actually see the planets in

the skies. This is called their *geocentric* position; and is very different from their real situation, as determined by a line passing from the sun's centre through the centre of each of them, till it terminates among the fixed stars. This last is their *heliocentric* place.

Though the sun is stationary in the centre; yet, as the earth is moving round in its orbit, the earth seems to be stationary while the sun appears to move along the opposite side of the ecliptic; as when we sail in a boat or ride in a carriage, the boat or vehicle seems to stand still, while the shore and surrounding objects appear to pass behind us. Thus; when the earth enters Libra, the sun appears to enter Aries; and always seems to be, with respect to the signs, directly opposite the earth.

By lines drawn from the earth through all parts of the orbits of the inferior planets it will be seen, that these planets must always remain near the sun. When they are at the greatest distance from the sun, on either side, they are said to be at their *quadratures;* that is, they are a quarter of a circle, or one fourth part of a revolution before or behind the earth. When they are in a line with the earth and sun, they are said to be in *conjunction.* If they are beyond the sun, it is called their *superior* conjunction, or *opposition:* but if between the earth and sun, it is the *inferior* conjunction.

When the inferior planets are at their superior conjunction, they seem to move forward along the signs; and their motion is said to be *direct.* But when these planets are at their inferior conjunction, their motion appears to be contrary to the order of the signs; and they are then said to be *retrograde.* And when they are at the quadratures, they seem to stand still, and are then said to be *stationary.*

The reader will readily perceive by inspecting Fig. 1. that, while the inferior planets are at or near their inferior conjunctions, his eye, while viewing them from the earth, will refer them to a directly opposite sign to that they are in. Thus; suppose Venus nearly in a line between the earth and sun, she will evidently be in the same sign of the ecliptic with the earth; but the eye of an observer placed on the earth, would refer her to the opposite side of the ecliptic. And as she proceeds *directly* along the signs on this side of the ecliptic, she will appear to move contrary to the order of those on the opposite side.

The distance that an inferior planet appears from the sun, at

either side of him is called its *elongation*. When at the quadratures, the elongations are the greatest. The greatest elongation of Venus is 47 deg. 48 m.; and that of Mercury 28 deg. 20 m. Hence Venus is seldom above the horizon more than 3 hours before or after the sun rises or sets; and Mercury, little more than 1¾ hrs.; and they can only continue so for a few days.

These planets, in moving round the sun, will sometimes when they are at the superior conjunctions, be hid behind him; and Venus will then pass behind Mercury; but when they are at the inferior conjunctions, Mercury will pass behind Venus. All the planets, as well as some of the fixed stars, occasionally pass behind the moon. Such occurrences are called *occultations*.

The inferior planets will also sometimes be in a direct line between the earth and sun; when they will be seen to pass over the sun's disc: an occurrence of this kind is called a *transit*. But transits very rarely happen.

By the assistance of fig. 2; and a recollection of what was said in section 3. respecting the proportional magnitudes of the sun and planets, with respect to their distances; and also what is said above of their elongations;—it will readily be perceived, that when Mercury is on either side of the ecliptic, a line from the earth continued through the planet towards the fixed stars, would not touch the sun: so that, Mercury, in either of its conjunctions, instead of being hid behind the sun or crossing the solar disc, would be seen above the sun at the one conjunction, and below him at the other. The elevation or depression will be the greatest when the nodes are at the quadratures.

But should the earth happen to be at one of these nodes while the planet is at it, namely, at its inferior conjunction, the planet will then be seen to pass directly over the centre of the solar disc: and if viewed through a telescope will appear like a black spot upon it. Should the conjunction not be exactly at the node, but within a certain distance, (if Venus within 1¾ deg.), there will nevertheless be a transit; but the planet will cross the solar disc either above or below the centre, according to the distance of the conjunction from the node. Hence, there may be many transits all partially differing from each other.

Now when there has been a transit of the planet Venus, if she took exactly the same time to revolve round the sun that the earth takes, we should have a transit every half year; namely, every June and December, at which seasons it may be seen by

Fig. 1. the earth is at this planet's nodes. But as the periodical revolution of the earth is greater by 140 days than that of Venus; at the end of half a year, when the earth comes to the other node, instead of Venus being thereat, she is one quarter of a revolution past it; and is at the quadrature instead of the conjunction. It must therefore be some years before another transit of Venus can possibly occur. The nearest transits to our times were in the years 1639, 1761, 1769, and the next will be December 8th, 1874.

Mercury's transits sometimes occur at the end of 6 years; oftener at the end of 7; and frequently at the end of 13, 36, or 46 years. The last was November 5th, 1822; and the next will be in 1832.

6. REAL AND APPARENT MOTION OF THE SUPERIOR PLANETS.

THE inferior planets are always to be found near the sun, which proves that their orbits are between the earth and the sun. But we may sometimes see the superior planets rising while the sun is setting, or on the meridian at 12 o'clock at night, when the sun is beneath the earth: in both cases the earth must be between the sun and the planets; and therefore the superior planets must be farther from the sun than the earth.

When a superior planet is on the same side of the sun with the earth, it is said to be in *conjunction with the earth;* but it is in *opposition to the sun.* And when it is beyond the sun, being then farther from us by all the width of the earth's orbit, it is in *conjunction with the sun,* but in *opposition to the earth.* When it is half way between these points, it is in its *quadratures.*

The apparent motions of the superior planets are *direct* when in conjunction with the sun; *retrograde,* when in conjunction with the earth; and, at certain points between their conjunctions with the earth and quadratures, they are *stationary.*

Jupiter, for instance, is retrograde when in conjunction with the earth: he then rises while the sun sets. At the end of about 60½ days he is stationary; and afterwards his motion is slowly direct. At the end of about 39 days he is at the quadrature; eastward of the sun; on the meridian while the sun is setting; and an evening star. In about 99 days more he is in conjunction with the sun, when his direct velocity is the greatest. The sun and planet then rise together, and therefore the latter is

invisible. But at the end of near 99 days more Jupiter is again at the quadrature; westward of the sun; a morning star; and on the meridian while the sun is rising. At the end of about 39 days more he is stationary; after which he is slowly retrograde for about 60½ days, when he will be again in conjunction with the earth; and his retrograde velocity will be the greatest.

7. THE SECONDARY PLANETS OR SATELLITES.

Of these, by far the most important to us is the Moon, a description of which is contained in chap. III.

Jupiter's Satellites.—When the planet Jupiter is viewed through a telescope, he is found to be attended by four satellites. Their mean distances, the time of their revolutions, and the mean inclination of their orbits to that of their primary, are as follows:

No.	Distance from ♃	Revolves round ♃				Inclination of orbit to ♃'s		
I.	264,490	1d.	18h.	27m.	33s.	3deg.	18min.	38sec.
II.	120,815	3	13	13	42	3	18	0
III.	674,234	7	3	42	33	3	13	58
IV.	1,180,582	16	16	31	50	2	36	0

The first and third satellites are the largest, and their diameters are about twice that of the moon; the fourth is nearly of equal magnitude with the moon; and the second is the least; though according to some calculations, the smallest is considerably larger than our moon.

The motions of Jupiter's satellites are of the greatest service both in astronomy and navigation. For by observing their transits over the disc, and their occultations in the shadow, and behind the body of their primary, astronomers have discovered the velocity of light, and mariners frequently determine the longitude at sea.

As the satellites make their respective revolutions in exactly the same space of time:—suppose, when Jupiter is in conjunction with the earth, a transit or obscuration of one of his satellites takes place at 8 o'clock. Now when in opposition to the earth, Jupiter is farther from us by all the width of the earth's orbit, or 190 millions of miles; and by calculation a recurrence of the same transit or obscuration is to take place precisely at 9 o'clock. But upon observation it is found to be 16

minutes later. Consequently light is 16 minutes in travelling across the earth's orbit; and it therefore must proceed at the rate of about 200,000 miles in a second. Hence, it appears that light is 8 minutes in passing from the sun to the earth; but a cannon-ball, travelling with the same velocity that it generally has when it leaves the gun, would be 30 years in performing the same journey. (For longitude, see chap. IV. s. 7.)

Saturn's Satellites.—Saturn has 7 satellites, but they cannot be seen without the aid of very large telescopes.

No.	Mean dis. from ♄ in miles.	Inclina. of orbits to ♄'s orbit.	Revolves round ♄ in			
I.	119,627	30deg.	0d.	22h.	37m.	23s.
II.	153,496	do.	1	8	53	9
III.	190,044	do.	1	21	18	26
IV.	243,449	do.	2	17	44	51
V.	340,005	do.	4	12	25	11
VI.	788,258	do.	15	22	41	14
VII.	2,297,541	24deg. 45m.	79	7	54	37

The 7th always keeps the same side towards the primary, and indeed Herschel supposed that *all* satellites do the same: the moon does so.

Uranus, according to Sir W. Herschel, is attended by six satellites; but they are still more difficult to be seen than Saturn's; and require the aid of very powerful telescopes.

No.	Mean dis. from ♅ in miles.	Incli. of orbits to orbit of ♅	Revolves round ♅ in			
I.	224,155	99deg. 43m. 53s.	5d.	21h.	25m.	21s.
II.	290,821	or	8	16	57	47¼
III.	339,052	81 6 4	10	23	3	59
IV.	388,718	all	13	10	56	30
V.	777,187	the	38	1	48	00
VI.	1,555,872	same.	107	16	39	56

The chief peculiarity of these satellites, is, the planes of their orbits are nearly perpendicular to the plane of their primary's orbit;—and it has been supposed that their motions are retrograde.

8. COMETS.

BESIDES the above bodies which compose our solar system, there are others that either belong to it or occasionally visit it. These are comets, which describe extremely elliptical orbits; indeed so much so, that it has been conjectured, they move round more suns than one. That is, they approach our sun, moving in almost a direct line; pass round him; and then, proceed in almost a direct line back again, till they disappear on account of their great distance; and, as the fixed stars are now presumed to be suns, it has been supposed that the comets may be attracted towards them, and pass round them as they do round our sun.

Some comets consist of a mere luminous vapour; while others contain near the centre of this vapour, what appears to be a solid body. This body or nucleus and its luminous vapour, form what is commonly called the head of the comet. The head is sometimes surrounded by an extensive atmosphere not luminous; which is again surmounted by a vast luminous envelope, called the coma, from which is extended a tail of the same luminous appearance, and of a prodigious length; always projecting from the sun in the plane of the orbit, nearly in a line with the centre of the sun and the head of the comet. The tail seems only to shoot out as the comet approaches the sun; and consequently the nearer the comet advances to the sun the larger and brighter is the tail. As the comet recedes from the sun the tail begins to diminish; and at length the whole comet assumes a globular appearance.

All comets and their tails have nearly the same shape; yet, they will have very different appearances, according to the position of the tail with the line passing from the spectator's eye to the head of the comet. At the end of their orbits, comets make a very sudden turn round the sun; and the tail having to describe a much larger curve than the head, is partly left behind; consequently, the tails of some comets have occasionally appeared a little bent or curvated. Sometimes it causes the appearance of two tails. But independent of this, some comets have exhibited more than one stream of light in the direction of the tail.

The *apparent* magnitude of some comets has equalled the sun; others have been compared in this respect to the moon; while many have rivalled the primary planets. One appeared in the reign of Nero whose apparent magnitude, according to Seneca,

was not inferior to the sun. Another appeared in 1652, apparently not less than the moon; but was much inferior in splendour, having a pale, dim light, with a dismal aspect. The *real* diameter of the nucleus of that comet which appeared in 1811, was only 428 miles—but the diameter of the luminous head was 127 thousand—and when extended to the outside of the envelope the diameter was not less than 643 thousand miles. The length of its tail was 80 or 100 millions of miles, and its breadth 15 millions. The tail of that which appeared in 1680 was nearly the same length.—But the diameter of the nucleus observed by Herschel in the comet of 1812 was 2,637 miles, while its tail was only 659,000 miles in length.

More than 500 comets are said to have been seen at various times since the christian æra. And, though many of these may be returns of the same; yet, according to Herschel, we are only sure of the return of one. This appeared at the following periods, 1456, 1531, 1607, and 1682. From the similarity of the description given of it at these periods, Dr. Halley supposed it to be the same comet; and predicted its return in 1759—which accordingly happened; and it will appear again in 1886, and every 75 years afterwards. Some philosophers assert that the periods of two more are known.—The first of these appeared in 1532, 1661, and it was expected to return in 1789, and in every 129 years afterwards. The other is that noted one of 1680; and its period is no less than 575 years. But the elements of the orbits of 99 have been correctly ascertained. Of these, in their nearest approach to the sun, 22 passed between the sun and Mercury; 40 between Mercury and Venus; 17 between Venus and the earth; 16 between the earth and Mars; and 4 between Mars and Jupiter. Fifty of them are said to have moved from east to west—or contrary to the motion of the planets.

Comets are extremely irregular in their motion, proceeding much the most rapidly when nearest the sun. In this position that of 1680 moved at the rate of 880,000 miles per hour; which is nearly 13 times more swift than the earth travels in its orbit. And while all the planets, except the asteroids, move nearly in the plane of the ecliptic, the comets have much wider ranges. The plane of the orbit of that comet which appeared in 1811, was nearly perpendicular with the plane of the earth's orbit: however the planes of others have nearly coincided with that of the earth.

From their cutting or threading the planes of the planets' orbits in almost every direction, it has been supposed that one may by chance come in contact with the earth; though some philosophers assert this cannot possibly happen. However, should any one maintain that such an event may probably take place in the stream of time, we need not conjecture what the consequences will be. Superstition may terrify itself with imaginary fears; but the christian knows by whose hands these immense bodies are wielded; that if they are propelled by Almighty power, they are guided by infinite wisdom; and that unbounded love governs the whole and directs all to some salutary end.

CHAP. II.

The Earth. (Astronomy and Geography)

1. LINES AND CIRCLES USED IN ASTRONOMY. 2. DAY AND NIGHT. 3. THE SEASONS 4. THE ARTIFICIAL TERRESTRIAL GLOBE. 5. LATITUDE AND LONGITUDE. 6. THE ARTIFICIAL CELESTIAL GLOBE. 7. DAY AND NIGHT REPRESENTED BY THE ARTIFICIAL GLOBE 8. VARIATION IN THE LENGTH OF DAY AND NIGHT. 9. TWILIGHT. 10. THE EARTH'S ORBIT AN ELLIPSIS. 11. ADJUSTMENT OF THE DAY. 12. PRECESSION OF THE EQUINOXES. 13. ADJUSTMENT OF THE YEAR, CHANGE OF STILE AND LEAP YEAR. 14. FIGURE AND CIRCUMFERENCE OF THE EARTH ASCERTAINED.

1. LINES AND CIRCLES USED IN ASTRONOMY.

THE planet which we inhabit, called the Earth, is a globe or sphere; and every man, on whatever part of the surface of this sphere, and at whatever hour of the day or night, imagines himself on its very summit;—and in astronomy he is admitted to be so. We shall suppose the reader to be situated about the centre of England; the time of the year, midsummer; and the hour of the day, 12 o'clock at noon:—the earth's position will, therefore, be properly represented by fig. 3; and the reader's situation will be at L.

The *axis* of the earth A B is an imaginary line passing through the centre of the sphere; which in astronomy is supposed to be extended in each direction till it pierces the heavens in the two opposite points. The end A, is called the *North Pole*; and B, is the *South Pole*.

The heavens are supposed to be inscribed with circles; and the planes of almost all these circles pass through the centre of the earth. Such as have their centres at the earth's centre, are called *Great* circles; but those that have

Fig. 3.

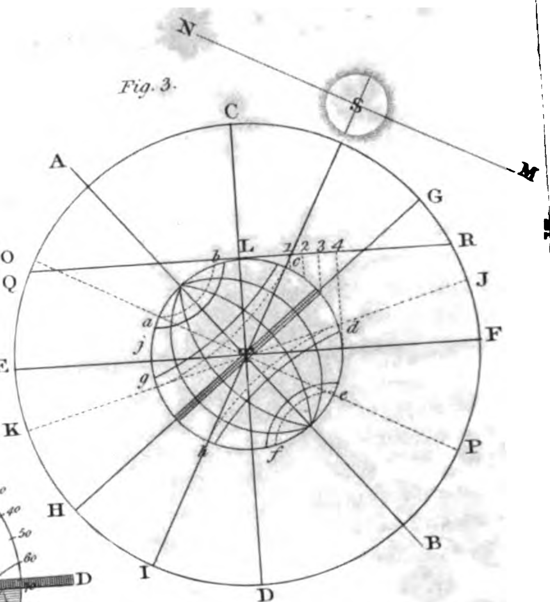


Fig. 5.

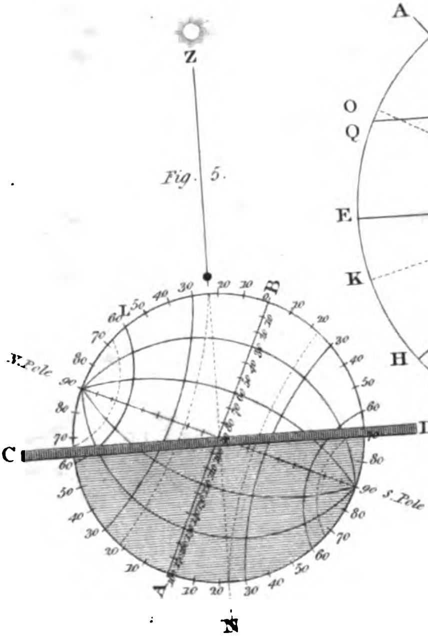


Fig. 6.

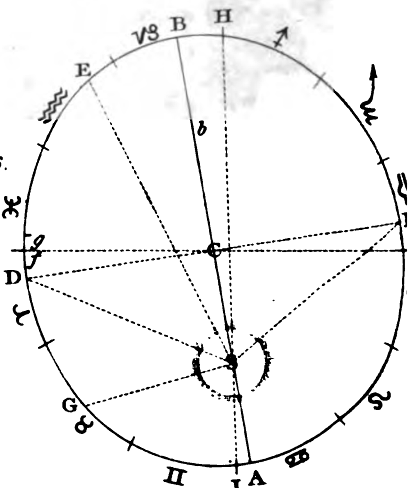
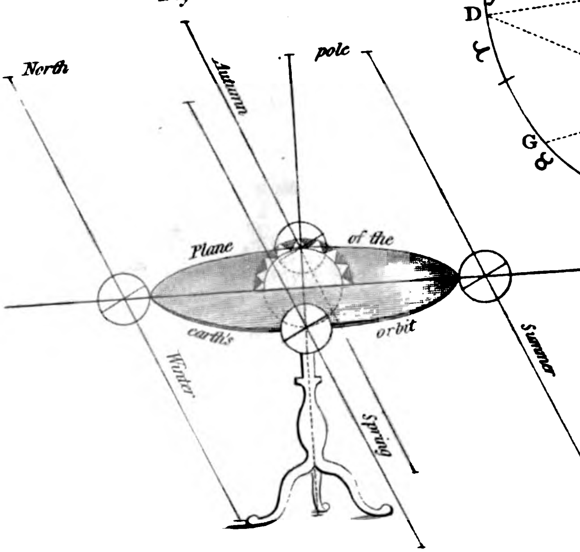


Fig. 4.



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have not their centres at the earth's centre, are called *Less* circles. All the lines therefore of Fig. 3, except the lines M N and Q R, are diameters of great circles. A diameter is always understood to pass through the centre of its circle, and to cut the plane of the circle into two parts. The space included within the circle A G B H is the *plane* of that circle; so that, any of the lines crossing each other at the centre T, may be considered as its diameter.

The *Meridian* is a great circle passing over-head, through each pole, round the heavens. In Fig. 3, the circle A B G H represents the reader's meridian; and, therefore, the line A B is properly the only diameter of this circle. As we may make many circles round a ball, all passing through two opposite points; so, every place on the earth's surface, not on the meridian of any other specified place, is supposed to have a meridian of its own. The number of these circles must therfore be considered as unlimited. Also, as they all pass through the poles, and their planes through the earth's centre, of course, the axis of the earth A B is a diameter to each of them; and every person must be in the plane of his own meridian.

Zenith and *Nadir*.—Since every one imagines himself on the summit of the earth, he will likewise suppose, that the point directly over his head is the highest in the heavens; and, as his feet are always directed to the earth's centre, so a line drawn from the point over his head, passing through his body, and continued indefinitely through the earth's centre, will pierce the heavens in the lowest point. The lower point D Fig. 3 is called the *Nadir*, and the upper point C, the *Zenith*, *Vertex* or *Vertical point;* and all lines passing through it, as the meridian of the place, are called *vertical* lines.

The *Horizon*.—Though we can see but a small part of the earth's surface from any one point; yet, on a clear night, half the stars are visible; that is, we can see from the zenith to a quarter of the circumference of the heavens, or 90 deg. on every side; which, measured from side to side, with vertical lines, is 180 deg.,—the whole circumference being 360 deg. The circle formed by the termination of our view all round, is called the *rational Horizon;* and its plane E F passes through the centre of the earth. But in the day-time we do not see so much of the heavens; the circle, therefore, formed by the sky apparently cutting the earth all round, is called the *sensible horizon;* and its plane Q R is supposed to pass through the eye of the spectator. The line of the zenith and nadir C D is some-

times called the axis of the horizon ;—and the planes of the two horizons are considered as parallel.

The *Ecliptic* is the most important circle in astronomy; consequently, the reader should be assured that he perfectly understands what is meant by it before he proceeds farther; otherwise, he cannot expect to become master of this sublime and beautiful science. In Fig. 1, the circles with the degrees, the signs, and the months marked on them, represent the *ecliptic;* the surface of the paper of that figure represents the plane of the ecliptic, which is also the plane of the earth's orbit; we must therefore transfer this figure to its proper place in the heavens; and adjust it to the earth's position at midsummer, or at 12 o'clock at noon on June 21st. We can therefore only represent a diameter of its plane, or the line called the line of direction of the earth and sun, which is marked S I, fig. 3. It must be remembered, that as the ecliptic is the circle made by the earth travelling round the sun, the sun, though in reality at its centre, will always appear on the opposite side; or speaking astronomically, will always be upon the ecliptic; and the earth, though really on the edge of the plane of its orbit, will, as this plane is extended on all sides indefinitely among the fixed stars, appear at the centre of the ecliptic. The line S I, therefore, can only represent one half of the diameter of the plane of the earth's orbit; although it may be allowed to represent the whole of the diameter of the ecliptic. As the diameter of the earth, in this figure, is one inch, were the line S I completed in its due proportion, it would be in length about 330 yards, and the sun's diameter would be above 111 inches.

As all the heavenly bodies appear at an equal distance from us , their apparent distances from each other, are measured by arcs of a great circle. The curve A C Fig. 3, is an arc,—and these distances are calculated in degrees. As the whole circle A B G H contains 360 degrees, the measure of the arc A C will be 38 degrees. This is also called the angular distance; the arc A C being the measure of the angle, formed by the two lines from the points A and C joining each other at the earth's centre T. But it should be observed, that this has no reference to the real distance of the objects; since they may be either two fixed stars, or the moon and a fixed star; or an object on the earth and a heavenly body.

As we have now arrived at what we consider the first difficult point in Astronomy, it will be of great service to the young

astronomer to make himself thoroughly acquainted with fig. 3. We shall therefore add an explanation of its principal parts, that he may have them all at one view.

A B. Axis of the earth: A North Pole, B South Pole.

C D. Zenith and Nadir line: C Zenith or Vertex, and D Nadir.

E F. Rational Horizon: E North, F South.

G H. Equator.

S I. Ecliptic—or plane of the earth's orbit.

J K. Represents the situation of the Ecliptic in Winter, as S I represents it in summer. S or K Summer Solstice, and J or I Winter Solstice.

N M. Axis of Ecliptic or axis of the plane of the Earth's orbit.

O P. Boundary line of light and darkness called the Terminator.

A G B H. Meridian, (a circle being generally represented by four points). The arcs S J and K I are sections of the Zodiac.

The above lines, supposed to be inscribed in the heavens, belong to Astronomy: the following, supposed to be described on the earth's surface, belong to Geography. But as those in the heavens are merely extensions of these upon the earth, the reader should accustom himself to form the continuation in his mind; and to assist him in doing so, we shall here give an explanation of the remaining lines and circles of this figure

The outer circle *a b c d e f h g*, and all the curves intersecting each other at the two poles A and B, are Meridians.

G H. Earth's Equator.—The half of the sphere towards the nort pole A is the Northern, and the other half the Southern Hemisphere.

a b. Arctic Circle;—and the space that it includes is the North Frigid Zone.

e f. Antarctic Circle and South Frigid Zone.

bc and *ag.* North Temperate Zone.

de and *hf.* South Temperate Zone.

c g. Tropic of Cancer.

d h. Tropic of Capricorn.

The space of the earth included between the two tropics is called the Torrid Zone.

The other arcs or circles, parallel to the tropics and arctic circles, are called parallels of Latitude.

2. DAY AND NIGHT.

BESIDES the revolutions already described in Chap. I. the planets have another motion, each turning round on its own axis, which is called their *diurnal motion*. This compound motion may be illustrated, by running an orange round in contact with the out edge of the plane of a round table. Let the place of the stalk and the opposite point, represent the poles of the earth; at half way between them, draw a line round representing the equator, and cutting the orange into two parts or hemispheres. The plane of the table will represent the plane of the earth's orbit: the sun being supposed at the centre, half above and half below the surface. Then, placing the finger and thumb upon the two opposite points of the orange, and applying the equator to the edge of the table; so, that one half of the orange, or the northern hemisphere may be above the table's surface, and the other half or southern hemisphere below; in this position roll it round from the west by the south to the east.

Once round the table will represent a year. But in performing this, the orange will have made several revolutions on its own axis. The earth makes 365¼; and each of them affords us a day and a night; for, as the sun is the source of light, and only one half of the earth is towards him at once, the cause of what we term *Day* and *Night* is very evident.

But another circumstance will here attract the attention of the young experimenter. He will perceive, when the orange has made one revolution on its own axis, that the same place will not be towards the sun: he must push it a little farther. So the earth completes a revolution on its axis in about 23 hrs. 56 min.; but requires 4 minutes more before the same place is exactly towards the sun, making a day and night to consist of 24 hours. (see Sec. 11.)

However the above illustration, if too closely examined, may, in one respect, mislead the understanding. The reader must bear in mind, that the earth, in revolving round the sun, touches nothing; and performs a part of its orbit equal to 1,632,000 miles every day: whereas, if it merely rolled round like the orange, or measured the space as a carriage wheel measures the road it passes along, it would only perform, each day, a part of its orbit equal to about 25,000 miles.

3. THE SEASONS.

As the plane of the table represents the plane of the earth's orbit; so, if a candle be placed directly over the centre in a line with the stalk of the table, the axis of this plane M N Fig. 3. will be thereby properly represented. And, supposing the axis of the earth A B represented by a straight rod passing through the poles of the orange, and these two axes parallel, or both perpendicular to the plane of the earth's orbit,—as the lines M N and O P Fig. 3. are parallel to each other, or perpendicular to the line S I we should, therefore, throughout the year, have day and night exactly of the same length; or as they are on the 21st of March or 23rd of September; and should, besides, have neither summer nor winter, nor any change of season.

But all, or most of the planets, have their axes variously inclined to the plane of their orbits. The inclination of the earth's, as represented by the two lines A B and S I Fig. 3. is considerable; being nearly 23½ deg. or the measure of the arc S G from perpendicularity: or, these two lines make an angle, (the angle A T S) with each other of nearly 66½ deg.—and to this we owe all the changes of the seasons, and all the variation in the length of day and night.

To illustrate this: suppose the surface of the table three feet high, the top of the candle, or any substitute, must be also three feet above it; making the axis of the plane of the earth's orbit 6 feet in length. But, as the axis of the earth's orbit, and the earth's axis are not parallel, the rod, passing through the orange and representing the latter, must be placed in a sloping direction, see Fig. 4.; and that its top may be of the same elevation with the top of the candle, or axis of the plane of the earth's orbit, its length, (to permit the lower end to rest upon the ground,) must be 6 feet 4½ inches.

Suppose, then, the plane of the table to be 4 feet diameter; the sun in the centre; and the orange, or earth at the middle of the rod. To represent the position of the earth at midsummer, or June 21st, the lower end of the rod, (allowing for the part of the orange intervening between the rod and the table,) must be 3 feet 3½ inches from the bottom of the table stalk, or axis of the plane of the earth's orbit, while their upper ends will be only 8½ inches apart. In this position it will be seen, that the line round the orange representing the equator will not be at the edge of the tabular plane, or plane of the earth's orbit, but will be

below it, a space equal to 23½ deg.; counting 90 deg. from the equator to the pole.

It must be carefully remembered, that the planets always keep their axes in the same parallelism. Therefore, when the orange is moved round to the opposite side of the table, the two upper ends of the axes will be at a greater distance than the lower ends. The equator, also, will then be as much above the table, as it was before below it; and this will represent the position of the earth on the 21st of December.

Now by the same invariable position of the axes, when the orange has advanced half way between these two opposite points, both the upper and the lower ends of the axes will be at the same distance; consequently, though the rod is still sloping, the equator will touch the table. This will be the case twice in the year, on the 21st of march and 23rd of September. The earth is then at the equinoxes, the day and night being equal.

As the earth is proceeding every moment in its annual revolution, and continually revolving on its axis; the same part will not be at the plane of the orbit two days together. If the earth be proceeding from winter to spring, the south pole will gradually recede from the sun, till the vernal equinox, when both poles are at an equal distance. And from the equinox till midsummer, the north pole will gradually incline to the sun; so that, if the place where the orange and table come in contact be marked on the orange, the line will be in a screw-like form; and the same being done in the other half year, they will cross each other.

The young student should be again reminded that the earth, in its progress, touches nothing; therefore, should he attempt to represent the seasons by applying the orange to the edge of the table, and at the same time to give the diurnal motion, he will not succeed. For the latter motion should be given, and the orange moved round in representation of the seasons, without its being in actual contact with the table.

Should the line representing the plane of the earth's orbit Fig. 3, be traced from S, to I on the opposite side of the figure; the student will see that it has crossed or cut the plane of the earth's equator; and that the point I is as much south of the equatorial point H, as the point S is north of G. Now, as we must here suppose the ecliptic to turn round, and not the earth; consequently, at midnight, the reader still being at L, if he look for the ecliptic, he will see the point J on the meridian, which is the

first point of Capricornus—or the place of the ecliptic wherein the earth is, being that directly opposite the sun: or should he suppose the earth to turn round, and the sun to remain stationary at S, his place at midnight will be at *j*, and the nearest point of the ecliptic, at I.

Half-a-year hence, when the earth is at the opposite point of its orbit, on Dec. 21st, the sun, at noon, will appear at the point J; and, at midnight, the other side of the ecliptic will appear where the sun is at midsummer, namely, at S.

At 6 o'clock, both morning and evening, summer and winter, the points of the ecliptic, cutting the earth's equator, will be on the meridian at G and H. When the earth is at the vernal equinox, the point I or J will be on the meridian at 6 o'clock in the morning; and, at 6 in the evening, K or S. And their positions will be reversed at the autumnal equinox.

4. ARTIFICIAL TERRESTRIAL GLOBE.

MANY difficulties in Astronomy and Geography may be solved by the use of artificial globes; but as these instruments are in the hands of comparatively few general readers, we shall here give directions for making a substitute. As the orange may be too small; we shall suppose the reader to take a ball of a foot diameter, as represented Fig. 5. Having perfixed a rod through the centre to represent the earth's axis and poles, and drawn the equator A B according to the directions given for the orange, he may consider himself in possession of a *terrestrial globe.*

Now as only half of the earth's surface is enlightened at once by the sun, a hole must be cut in a board, or a piece of strong pasteboard C D, large enough to permit the globe to turn easily round: the poles preventing it from slipping through. This board will be the terminator, or boundary between day and night: above is day and below is night.

In Fig. 3. the reader is considered as on the summit of the earth; and the terminator O P is, at its north end, considerably elevated above the horizon E F: but in Fig. 5, for the sake of convenience, the sun must be considered as in the vertex. That Fig. 3, and Fig. 5 may, in this respect, be made to agree,—the book must be turned round till S I Fig. 3. come to represent the line of the zenith and nadir, or the line from the sun to the earth's centre, Fig. 5.

5. LATITUDE AND LONGITUDE.

DRAW a circle through the poles, all round the globe; which will cut the equator at right angles on the opposite sides: or, in Fig. 5, at A and B passing through the N. and S. poles. Call this circle a *meridian.*

The globe is now circumscribed with two circles at right angles to each other. These circles must each be divided into 360 deg.; and a mark must be made at every 10 deg. The degrees on the meridian are counted each way from the equator towards the poles; so that, this meridian circle will be divided into four parts, each numbering 90 degrees.

Through the above divisions on the meridian, circles must be drawn parallel to the equator, called *parallels of Latitude.* So that Latitude is counted from the equator along the meridians towards each pole; and therefore can never exceed 90 degrees. That towards the north pole is called *northern*, and that towards the south pole, *southern* Latitude.

As a whole circle contains 360 degrees; so, from the place where the meridian on one side crosses the equator, to where it crosses it on the other side, counting each way along the equator, are 180 deg. These are called degrees of *longitude.* And if the reader turn the south pole of his globe towards him, having the plane of the meridian vertical; then, those on the right side will be *east* longitude, and those on the left, *west* longitude. A mark being already made at every 10 degrees, draw a line from pole to pole through each of them; and they will be the lines of longitude: which is counted each way along the equator to 180 deg. The lines of longitude are also meridians; and longitude is counted from the meridian of London or Greenwich. But every country calculates from a meridian of its own;—while latitude is always reckoned from the equator.

By the help of these lines, the situation of any particular place on the surface of the earth, may be easily transferred from a map to its corresponding place on the globe. Thus: the situation of London may be marked upon the meridian of that place, a little beyond the fifth parallel of latitude, or at 51½ degrees of N. latitude.

As these imaginary circles of the terrestrial globe are extended to the heavens, the latitude of any place on the earth may be ascertained by the assistance of the heavenly bodies. For instance; knowing the altitude of the sun to be at London, when

on the meridian, that is, at 12 o'clock at noon, on June 21st, so much short of 90 deg. (the altitude of the zenith,) as the sun is distant from the zenith; by finding the sun's altitude at any particular place, the latitude of that place may be determined. Thus: London is at 51½ deg. north latitude; and the sun on the 21st of June is vertical over 23½ north latitude; consequently, the sun is 28 deg. from the zenith of London; or, 62 deg. high, which is the complement of 90 deg.

Now if by observation on any part of the earth's surface northward of the sun, the altitude be any number of degrees less than 62, the latitude is known to be so many degrees to the northward of the parallel of London. Should the altitude be more than 62 deg., then, the place is so many degrees southward of London.

Should the sun be northward of the observer; and he find the altitude, when at the meridian on that day, 66½ deg.; then, he knows that he is in no latitude: being upon the equator; or, as the sailor expresses it, is "crossing the line."

The same may be observed with respect to the altitude of the sun on any other day of the year; his distance from the equator, when on the meridian on that day being known; and it is the same with any other of the heavenly bodies whose meridian altitude at any particular place is known. It is also the same in all latitudes and longitudes. (For finding longitude see Chap. IV. sec. 7)

6. THE ARTIFICIAL CELESTIAL GLOBE.

THIS globe differs nothing, as to shape, from the one already described; but the reader is supposed to be at its centre, while he is on the surface of the other. In short, the lines and circles of the celestial globe are those of the terrestrial transferred to the heavens: (see explanation of Fig. 3.) As the terrestrial globe has the various countries and seas described on its surface; so, the surface of the celestial contains the fixed stars, as they are divided into constellations; each star having the same position that it occupies in the heavens: (see Chap. IV. s. 12.) The globe being rectified to the latitude of the place, and hour of the night, as in Fig. 3. and the experimenter's eye being always supposed at the centre of the globe; then, were holes cut for each star through the place which it occupies on the sur-

face, he would, through each hole, see its respective star in the heavens.

The latitude or longitude of the heavenly bodies differs considerably from that of places on the earth. The latitude of terrestrial objects is counted from the equator; while that of the celestial is calculated from the ecliptic. The longitude of the latter, instead of being counted each way from a meridian like that of terrestrial objects, is calculated from the first point of Aries, in the order of the signs, all round the equator; the distance being represented by so many signs and degrees. Were a planet, therefore, only 10 deg. west of the first point of Aries, its longitude would be said to be 11 signs 20 deg. But sometimes this is called *right ascension;* and then, the distance from the first point of Aries is calculated in time: 15 deg. being equal to an hour. And latitude is sometimes called a star's *declination*, which is counted from the equator.

The angle, which the ecliptic makes with the equator, is called the *obliquity* of the ecliptic; and is equal to about 23½ deg. as has already been shewn. The ecliptic crosses the equator, upon the celestial globe, at two opposite points. At half-way between these points, the ecliptic extends, on each side, 23½ deg. These two latter points are called the *solstices;* because the sun at the two opposite seasons, winter and summer, here seems to make a stand before he retreats;—while the two former points, where the ecliptic crosses the equator, are called the *equinoxes;*—because when the sun is at these two points, the day and night are of equal length.

By these four points, namely, the two equinoxes and the two solstices, the ecliptic is divided into four parts; and the points are called the four *cardinal* points. The two meridian circles passing through these points are called *colures*. The one passing through the equinoctial points is called the *equinoctial* colures; and the other passing through the solstices, the *solsticial* colures.

The altitude of any heavenly body is counted along the quadrant of a circle extending from the vertex, through the body to the horizon, (the rational horizon being always in such cases understood.) The measure of the arc between the body and the horizon is the altitude.

The horizon is divided into two parts by the meridian cutting it at the north and south. Should a heavenly body not be on the meridian, its vertical line of altitude will cut the horizon to

one side of the ends of the meridian; and the arc of the horizon, included between the meridian and the vertical line of altitude, is called the *azimuth* of that body;—and is said to be so many degrees east or west.

The *amplitude* of a heavenly body refers to its rising or setting; and is counted from the east and west points, where the equator cuts the horizon. That arc of the horizon, between either of these points of the equator, and the point, whether north or south, at which the body cuts the horizon, is called the measure of its amplitude.

7. DAY AND NIGHT REPRESENTED BY THE ARTIFICIAL GLOBE.

SUSPEND by a thread from the ceiling, as at Z Fig. 5, a small leaden weight with a point; the point being downwards. Consider the line of this thread the plane of the earth's orbit; and the sun as situated at the upper end of it. Place the globe so, that the point of this weight may nearly touch the meridian of London where it crosses the equator; and the young astronomer will have an exact representation of the earth's position on the 21st of March or Sept. 23rd: being 12 o'clock at noon at London, as well as at all places from pole to pole along that half of the meridian; while the places over which the other half passes will have midnight.

The sun is now said to be on the meridian of London: all round where the globe touches the board is twilight. At the eastern side the sun is setting to the inhabitants, being 6 o'clock in the evening; and on the west, as they are just ascending into day-light, the sun is rising, and it is 6 o'clock in the morning.

Now as the circumference of the earth is 360 deg. and as the sun completes them all in 24 hours; he must pass over 15 deg. every hour. Turn the globe eastward till the point of the weight be at one division and a half, or 15 deg. west of London; and it will be 1 o'clock at that place, frequently represented by P. M. that is, *post meridiem*, or after the sun has crossed the meridian. Turn it 15 deg. farther, and it will be 2 o'clock at London; and so on, till 6, when the meridian of London will be at the terminator, or at sun set.

When the globe has been thus moved half way round, it will be midnight at London. Then begins A. M. that is, *ante meridiem*, or before the sun comes to the meridian. At 6 hours

after midnight, London will be at the terminator, or at sun-rise; and at 6 hours more, the meridian will be again at the weight, or it will be 12 o'clock at noon.

In this revolution the young astronomer will have perceived, that all the earth's surface has passed through day-light; while the poles have all the while been at the boundary of light and darkness. This is the case two days in the year; namely, on March 21st and Sept. 23rd, or at the two equinoxes.

A man sailing westward round the world would lose a day; and one sailing eastward, from the same port, would gain a day; so that, when they arrived in that port, their calculations of time would differ *two* days.

8. VARIATION IN THE LENGTH OF DAY AND NIGHT.

THE equator continues only one day at the plane of the orbit, or exactly opposite the sun; but in the progress of the year towards midsummer, the sun seems to come every day nearer to us, who live more than half way between the equator and north pole.

To represent this by the artificial globe; the north pole must every day be raised a little above the board; and the south pole depressed proportionately below it. This is equal to about 15 minutes or 17½ English miles a day. Therefore, every time the meridian of London comes to the weight, the weight will point to a place about 15 minutes farther north than on the preceding day. This will continue till midsummer, when the weight will be at nearly 23½ deg. the summer solstice, or where the sun halts and then retreats. Fig. 5. represents the globe in this position.

Should the globe be turned round, while in this position, the small weight will circumscribe a line parallel to the equator, which is the *tropic of Cancer.*

At the place where the globe touches the board 23½ deg. under the north pole, circumscribe a line, for the *arctic circle.* Then draw corresponding lines in the southern hemisphere for the *tropic of Capricorn,* and the *antarctic* circle, as shewn at page 19. These lines are generally dotted on the maps and artificial globes, to distinguish them from the parallels of latitude.

While the globe is in this position, one half being always above the board, there will still be 90 deg. from all sides of the weight to the board; so that half of the world is always in day-light. The experimenter will also observe, that if the line Z N,

representing the plane of the orbit, were continued, it would still pass through the globe's centre.

Having the meridian of London and the tropic of Cancer at the weight, it will be 12 o'clock at London on the 21st of June. Turn the globe eastward till London cuts the board; counting how many meridian lines pass the weight, one and a half being an hour; and it will appear, that the sun sets 20 minutes past 8 o'clock at London; and rises 20 minutes before 4, making the day almost 17 hours long.

All that part of the globe beyond 66½ deg. north latitude, will, in this revolution, never descend below the terminator: consequently, there will be no night. While, on the contrary, a corresponding portion round the South Pole will never ascend into day-light.

It is perhaps needless to tell the young astronomer, that the globe now, as represented Fig. 5, represents summer in the northern hemisphere; and winter in the southern. And, that to represent winter in the northern, and summer in the southern part of the world, the south pole must be as much elevated above the board as it is now depressed; and the north, depressed as much as it is now raised: when the length of the day and night will be reversed.

With the above directions, he will be enabled to find the length of day and night at any place whatever, on any particular day of the year. Thus: on the 1st of May, the weight will be at 15 deg. 9 m. on the meridian of London; and the sun will be found to rise 20 minutes before 5 o'clock, and set 20 minutes after 7. Also, when it is at 12 o'clock or any other hour with himself, he may find the hour of the day at any other place. When it is 12 at London or Boston in Lincolnshire, it is half-past 11 at the Land's End, the most westerly point of England. At Philadelphia, North America, 7 A.M. At Washington, 6 A.M. Midnight under the meridian of New Zealand. 10 P.M. at Botany Bay; and 6 P.M. about the mouth of the Ganges, or at Calcutta.

The experimenter will further observe, that around the two Poles, the inhabitants, if there be any, can have but one day and one night in the year. All that live within the Arctic Circle must, at midsummer, see the sun circling round them without setting. If they are not at the Pole the sun will be twice on the meridian in 24 hours; but, of course, higher at our noon than at midnight.

Suppose the observation is made at 80 deg. north latitude. Then, on the 21st of June, when the sun is on the meridian at noon, he will be directly south 33½ deg. high, or about as high as we have him in England the first week in March or the second week in October. But when the sun is on the northern part of the meridian, or, it is what we would call midnight, he will be seen over the north pole with an altitude of only 13½ deg.

Nevertheless, if viewed from the pole, this variation of the sun's altitude could not take place; but he would be seen to circle round 23½ deg. above the horizon; or, as high as he is at London, when on the meridian, about Nov. 18th or Jan. 23rd. At the autumnal equinox, the sun would be on the horizon, would then set or disappear; and be no more seen till the vernal equinox, when he would rise, and thence increase in altitude till the 21st of June.

9. TWILIGHT.

THOUGH we have said that the board of the artificial globe, or C D Fig. 5. is, as being the place where the sun rises and sets, the boundary of light and darkness; yet this was merely done to avoid greater inconveniences. It is well known that there is day-light in the sky, for a considerable time before and after the rising and setting of the sun; which interval of time is called *twilight*.

The rays of the sun falling upon the upper part of the atmosphere, are bent or refracted downwards; (see Chap. VIII. s. 2.) and the light thus afforded, continues till the sun is sunk 18 deg. below the horizon; or commences in the morning at the same distance before he arrives at it. When the sun is at the equator these 18 deg. being turned into time, are equal to 1 hour 12 min. and make the day from the time, that it first dawn in the east, to its last glimmering in the west, 14 hrs. 24 min. long. But when the sun is at the summer solstice, the young astronomer will perceive, by turning his globe, that no part of England is ever 18 deg. below the horizon; consequently, at midsummer, we have no night; and in the north of Scotland, the sun, at midnight, is little more than 8 deg. below the horizon.

From this it will appear, that they have much less twilight in the torrid zone, than in either of the temperate zones; and that in the frigid zones they have twilight for nearly 6 weeks toge-

ther. The density of the atmosphere is also greater around the poles; and this increases its refractive powers still more; so that, it adds two or three days to the above periods. These periods of twilight, being twice in the year, greatly curtail their long and dreary nights.

10. THE EARTH'S ORBIT AN ELLIPSIS.

For the sake of avoiding greater inconveniences, we have hitherto treated of the orbits of the planets as if they were circles, while, in fact, they are ellipses, having the sun in one of the foci.

Fig. 6, is an ellipsis; and the points S and *b* are its foci; at one of which S is the sun. But as the mean distance of the earth from the sun, is 95 millions of miles; and the eccentricity only about 1½ millions; it differs so little from a circle, that it is scarcely perceptible in a figure drawn on paper, if the due proportions are preserved. For if the shorter distance A S be represented by two inches; then the longer S B should be only a sixteenth part of an inch more; therefore in this figure the reader must not look for accuracy of proportion.

The line S D is equal to the mean distance; the space between C and S is the eccentricity, which in the earth's orbit is equal to 1,618,000 miles; this added to the mean distance, 95,000,000 gives the distance S B 96,618,000 miles, which is the greatest distance of the earth from the sun. It is called the *aphelion* distance; and the point of the orbit B is called the *aphelion.* The space A S represents the *least* distance of the earth from the sun; and is equal to the difference between the mean distance and eccentricity, or 93,382,000. The point A is called the *perihelion.*

As the earth is at the aphelion point B in summer, and at the perihelion point A in winter: it is evident that we are nearer the sun in winter than in summer, by twice the eccentricity or 3,236,000 miles.

The line A B, called the line of *apsides,* is not stationary; that is, it does not continue at the same two opposite points of the ecliptic; but its two ends, or the aphelion and perihelion points, are continually advancing in the order of the signs. This progression is equal to 1 deg. 44 min. in a century; so that, it would require about 20,700 years before the line of apsides would make a complete revolution. The perihelion A coincided with the

vernal equinox, or was at *f*, about the year 4089 before Christ; was at the winter solstice I in the year 1250 of the Christian æra;—and will be at the autumnal equinox or *e* in the year 6483.

A planet does not proceed with the same velocity through all parts of its orbit. Its motion is quickest at the perihelion, and slowest at the aphelion. It was discovered by Kepler, that the planets pass over equal areas of their orbits in equal spaces of time. Thus: suppose that part of the orbit, included within A S G, equal to that within B S E, then the earth will be the same time in travelling along the short space of the ecliptic between B and E, that it is the much longer space included between G and A. The earth's daily progress through the signs is, when at the perihelion 61 min. 11 sec. but at the aphelion it is only 57 min. 10 sec. being one fifteenth less: making a mean of 59 min. 30.

By this accelerated motion, the earth performs the half of its revolution D A F, in about 8 days less than the other half:—hence, the summer half-year is longer than the winter half. But the two areas of the plane of the orbit bear the same proportion to each other: the part D S F B, being considerably larger than D S F A.

11. ADJUSTMENT OF THE DAY.

IT is found that a good clock, going right all the year round, will often vary from the time of day as shewn by a sun-dial. For, though the earth always revolves on its axis in exactly the same space of time; yet, owing to the inclination of the axis to the plane of the orbit, and to the different velocities at which the earth moves in its orbit, the same place will not, after the same intervals, be exactly opposite the sun.

From Dec. 24th till April 15th, the clock will be before the sun; thence to June 16th, the sun will be before the clock; from this period to Aug. 31st, the clock will be again before the sun; and thence to Dec. 24th, the sun will be before the clock. From this it appears the sun and clock will be together four times in the year.

Draw an ecliptic circle upon the globe, as represented by A *e*, *b* B Fig. 8; and divide the quadrant from A to *b* into any number of equal parts, suppose two, by the point *e*; and the corresponding part of the equator A *d* also into two equal parts by the point *f*.

Now were the sun to proceed along the equator, the clock and sun would be always together. Suppose, then, the clock to keep the equatorial time, while the sun proceeds along the ecliptic; it will be found, when the globe is moved so as to represent the sun advancing from the vernal equinox A, to the summer solstice *b*; that the point *e*, where the sun is on the ecliptic, will come to the small weight before the point *f* on the equator is opposite to it: consequently the sun will be before the clock. But they will both arrive at the line E F at the same time, and will be together.

When they are past this line, and the sun is proceeding along the curve *b* B, the point on the equator will come opposite to the weight, before the point on the ecliptic touches it. They will be together again when the sun arrives at B; and the same might be traced through the other quarters.

The other part of the equation arises from the different velocities with which the earth proceeds in its orbit. The variation is the greatest about March 30th, and October 3rd; and least, or nothing, about July 1st and December 31st, when the earth and sun are at the apsides.

Suppose the earth at the aphelion point B Fig. 6; then the sun will appear at A; and while the earth moves in its orbit from B through the points E D G to A, the sun will appear to move from A through F to the point B. And suppose an imaginary star to leave the point A along with the sun; and to travel likewise round the ecliptic, but with a daily equable motion; while the sun, by reason of the earth's unequal motion, will proceed with an unequal motion. Now we must suppose the star to keep the mean time, or the time of a well regulated clock, while the sun shews the apparent time. As the motion of the earth when at B, is the slowest; and the sun and star are now together on the meridian; on the next day, when they come to the meridian, the star will have advanced further than the sun; and as the earth turns round on its axis from west to east, that is, in the order of the letters B E D G A F, the meridian will come to the sun before it comes to the star. Suppose, on Oct. 3rd, when the variation is the greatest, that the star is at the line D F, while the earth is only at *f*; the sun will then appear at *e*, while the star is at F; it is evident, therefore, that the meridian will come to *e*, before it arrive at F; and consequently, the sun will be before the clock.

But as the earth's motion is now every day accelerated; by the time the earth arrives at A, when its velocity is the greatest, the sun will have overtaken the star; and they will be both at B; consequently, the clock and sun will be together.

As the earth's motion is greater than the mean motion, through the other half of the orbit, the sun will be before the star; and the star will be on the meridian before the sun; or, the clock will be before the sun.

In this latter case the clock and sun-dial are together twice in the year, viz. when the earth is at its apsides; whereas, by the obliquity of the ecliptic, they are four times together, that is, at the four cardinal points. Therefore, to make a regular table, which shall point out the exact space of time, that the clock and sun will vary every day in the year, the above variation must be compounded. Such a table is given in most almanacks, and is called the *Equation of Time*.

The irregularities of the earth's motion, (and the motions of all the planets are as irregular), very much increase the difficulties in astronomical operations; and another circumstance farther augments them, viz. the line of apsides A B, Fig. 6, does not coincide with the solstices, H I: they differ 9 deg.

The time in which the earth makes one complete revolution on its axis, as shewn by a fixed star's leaving and return to the meridian, is 23 hrs. 56 min. $4\frac{1}{10}$ sec. of mean solar time. This is called a *sidereal* day. In the course of a year, these 3 min. $55\frac{9}{10}$ sec. daily required to bring the sun to the meridian, amount to a sidereal day;—so that, there are 366 sidereal days or complete revolutions of the earth on its axis, for 365 solar days:—though this varies a little by the precession of the equinoxes.

The *astronomical* day differs from the *civil* day. The former is counted from the time the sun is on the meridian one day till he is on the meridian the following day, numbering to 24 hours; while the latter is counted from midnight to midnight, having 12 hours A.M. and 12 hours P.M. The astronomical day is 12 hours behind the civil day. For example, June 23rd, at 5 o'clock in the afternoon the two days may be considered, with respect to the numbering of the hours, as together; but 5 o'clock the following morning, it will be, according to the civil day, June 24th; while it is only June 23rd 17 hrs. by the astronomical day.

12. PRECESSION OF THE EQUINOXES.

The inclination of the earth's axis to the plane of the orbit is not permanent; but is continually diminishing at the rate of about half a second every year, or $52\frac{1}{10}$ seconds in a century. The obliquity of the ecliptic is now, 1824, 23 deg. 27m. 48¼s.

Hence, after the equator has left the vernal equinox, and before it arrive at the autumnal, the inclination will have diminished one quarter of a second. The axis being therefore so much nearer perpendicularity, the equator will come to the plane of the orbit before the earth has completed a full half of its revolution.

Suppose *e*, Fig 6, the exact point where the equator touches the plane of the orbit at the vernal equinox; then, if the inclination remained the same, *f* would be the point for the autumnal equinox; but, as it has altered a quarter of a second, it will cut it at *g*, 25⅛ seconds of a degree, or nearly 10 min. 12 sec. in time, before it comes to *f*.

These 50¼ sec. per annum are equal to 30 deg. in about 2,149 years; or a complete revolution in about 25,790 years. And, as the equinoctial points determine the signs, it is evident the signs must be moving backwards, so far as the ecliptic is marked out by the fixed stars. This motion is called the *precession* of the *equinoxes*.

By reason of the precession of the equinoxes, the stars, which were 2,149 years ago in Aries, are now exactly in Taurus; and all the other stars of the zodiac are likewise one sign advanced. Hence, we see on the celestial globes, or on the wooden horizon of the terrestrial, the figure of the ram ♈, removed about 40 degrees from the first point of Aries. This, carried back, would lead us to determine, that it is about 2,865 years since the zodiac was divided into signs, or since the constellations of the zodiac were formed.

Between every 71 and 72 years the equinoxes will have preceded one degree, or be one degree nearer the line of apsides; consequently, celestial globes, that are 72 years old, will exhibit the fixed stars one degree from their proper places with respect to the numbering of the signs; and therefore they should be renewed once in that period.

13. ADJUSTMENT OF THE YEAR, CHANGE OF STILE, AND LEAP YEAR.

As the two solstices are at an equal distance between the two equinoxes; it is evident from what was said, Section 12, that the space of time included between the moment the earth leaves the summer solstice to the moment of its return, will be less than that taken up from the earth's leaving and return to a fixed star, by the time required to move over the 50¼ seconds, which the equinoxes have retrograded. The former is called the *tropical* or *solar* year; and is found to consist of 365 days 5 hrs. 48 min. and 48 sec.; and the latter, called the *sidereal* year, consists of 365 days 6 hrs. 9 min. 12 sec.:—making a difference of 20 min. 24 sec.

The *civil* year, which is made to consist of 365 days 6 hours, is nearly a mean between the tropical and sidereal year. But the civil year will thus exceed the tropical, 11 min. 12 sec.; and this excess was the occasion of the change of stile in the year 1752.

At the Council of Nice, A. D. 325, the calendar was adjusted, but the 11 min. 12 sec. were not noticed; nor indeed were they, till they had caused the fasts and festivals to be 11 days removed from the seasons at which they were originally fixed. In 23,783 years, this, had it not been rectified, would have made midsummer fall in December; or, in other words, the seasons would have been reversed with respect to the months. Therefore at the change of stile, 11 days were cut off to bring the fasts and festivals back again. And, to keep them always at the same seasons, it was found necessary to leave out the leap year at the end of every century not divisible by 4. Thus, the centuries 17, 18, 19, otherwise leap years, and containing 366 days, only contain 365. But the old terms go on as usual, at the rate of 18 hrs. 40 min., (though to keep the calendar correct according to the above statement it should be only 18 hours), in a century; so that, in about 47,000 years they will have gained a revolution of the new, and both will be together again.

That the odd 6 hours of the civil year may be taken into the account, a day is added every fourth year, except in the centuries above mentioned, to the end of February: making that month to contain 29 days instead of 28. On this account it is

called *Leap-year;* because it *leaps* or passes over a day. Thus; if the 1st of March be on a Monday, in the next year, not being leap year, it will be on the Tuesday; but if leap year, it will leap over Tuesday and fall on the Wednesday.

It is sometimes called Bissextile; because, when the year was made by Julius Cæsar to consist of 365 days 6 hours, sometimes called from him "The *Julian* Year," the 6th day of March was doubled for the additional day of the leap year; hence, *Bis-sextile,* that is, of or belonging to twice the sixth.

14. FIGURE AND CIRCUMFERENCE OF THE EARTH ASCERTAINED.

THE true shape of the earth is not that of a perfect sphere, but of an *oblate spheroid,* being a little flatted at the poles like an orange. The axis or polar diameter is 34 miles shorter than the diameter of the plane of the equator. This was discovered by Sir I. Newton, (see Chap. 5. s. 4.) but at the same time that he made the discovery, a foreign astronomer, named Cassini, asserted the earth's figure to be that of a *prolate* spheroid; or that its poles are a little extended instead of flatted. To settle the dispute, the King of France, Louis XV. sent out two parties of astronomers; the one party, to measure a degree of latitude upon the meridian near the arctic circle; and the other, to do the same at or near the equator. This was done in Lapland and Peru; and the result of their laborious travels established what Newton had demonstrated in his closet.

The principle on which they proceeded, and on which one means of finding the circumference of the earth is founded, is as follows.—Having fixed on a star in the zenith, and on another at one degree to the north or south of it; then, measure the space along the earth's surface to the point whereat the second star is in the zenith; or what is the same thing, till the first star is one degree to the north or south. The space thus measured will give the length of a degree upon the earth's surface; which is found to be nearly equal to $69\frac{1}{5}$ English miles. And as the number of degrees in the whole circle surrounding the earth is 360, so, the whole circumference of the earth will be 24,912 miles.

But as the French astronomers found, that the space measured under the equator, was less by 4,200 feet, than that near the arctic circle; so, they concluded that the curvature of the

earth's surface is greater, or forms the arc of a less circle, across the equator, than it does across the arctic circle; consequently, that the polar diameter must be shorter than the equatorial.

It is evident that what we call a level along the earth's surface, is not in a straight line or tangent from any point, as the line Q R, Fig 3.; but a curve, which falls below the straight line about 8 inches in the first mile; four times that, or 32 inches in the second mile; nine times 8, or 72 inches in the third mile; and so on, increasing as the square of the distance: (see the lines 1, 2, 3, 4, Fig. 3.)

Hence, seeing a ship at sea, the height of whose masts above the surface of the water we know, we can determine its distance. Suppose, for instance, the top of the ship's main-mast have an elevation of 100 feet above the surface of the sea; the spectator's eye an elevation of 50 feet; and the top of the mast be just visible in the horizon. Then the two elevations added together will give 1800 inches; which divided by 8, will give 225; the square root of which is 15, that is miles, the distance of the ship.

CHAP. III.

The Moon. (Astronomy)

1. Magnitude, Orbit, and Motion. 2. Phases or Change 3. Lunar Day and Night. 4. The Earth as viewed from the Moon. 5. Eclipses. 6. Solar Eclipses. 7. Lunar Eclipses. 8. The Harvest Moon. 9. Tides.

1. MAGNITUDE, ORBIT, AND MOTION.

The Moon is a secondary planet revolving round the earth in the same manner as the earth moves round the sun. This luminary has no light of its own; but like the earth, has always one half of its disc obscured in darkness, and the other illuminated with the solar rays; some of which, in certain positions, are reflected to the earth and constitute our moonlight.

The moon's diameter is 2161 miles, which is a little more than one fourth of the earth's diameter; but the earth, in cubic magnitude, is about 48 times larger than the moon. The lunar orbit is elliptical; the mean distance from the earth's centre is 236,267 miles; and the mean eccentricity 12,960; so that, in one part of the orbit the moon is 249,227 miles from the earth, and in the opposite part only 223,307. The point of the moon's orbit nearest the earth is called the *perigee;* and that at the greatest distance the *apogee.* The line joining these points and passing through the earth's centre is the line of *apsides.*

From the time of the moon's leaving a fixed star in the zodiac, till her return to it again, is 27 days 7 hrs. 43 min. 11½ sec. But at the end of that time, and before the moon overtakes the earth, the earth will have advanced 29 dég. 6 min. 20 sec. in its orbit; so that the time from one new moon to another, called a lunation, is 29 days 12 hrs. 44 min. 2¾ sec.

The moon's mean progress round the earth is at the rate of about 2,290 miles per hour; at the mean daily rate of 13 deg. 10 min. 35 sec. along the ecliptic. But this planet's motion, like that of all the secondaries, is very irregular. The velocity is the greatest at full and change, but especially at change; and the least at the quadratures. In every revolution the lunar orbit varies in eccentricity; and the greatest irregularity is when the line of apsides is in a line with the earth and sun. But when this line is in the quadratures, the eccentricity of the orbit is the least. All these irregularities are caused by the interference of the sun; and, therefore, when the earth is at the perihelion the sun's influence is the greatest. The moon then describes the largest orbit, and is somewhat longer in performing a revolution, so that the lunar month is observed to be a little longer in winter than in summer. By reason of the above irregularities in the moon's velocity, she does not, as the primary planets do, describe equal areas of her orbit in equal spaces of time.

In revolving round the earth, the moon always keeps the same side towards the earth; so that the time, in which she completes a revolution on her own axis, is precisely equal to the time of one lunation, or 29 days 12 hrs. 44 min. 2⅘ sec.

The plane of the moon's orbit does not coincide with that of the earth. The orbits make an angle, at a mean, of 5 deg. 9 min. but this angle is continually varying, being when at the greatest 5 deg. 18 min.; and when at the least only 5 deg. On account of the want of coincidence in these planes, half of the lunar revolution is performed on the north side of the ecliptic, or in northern latitude; and the other half on the south side or in southern latitude. The points where the moon crosses the ecliptic, or cuts the plane of the earth's orbit are called *nodes*.

The line of the moon's apsides is continually changing place, advancing all round the orbit in 8 yrs. 312 days 11 hrs. 11 min. 39½ sec. The moon will, therefore, in every lunation cut the plane of the earth's orbit a little before she arrives at the place whereat she cut in the preceding revolution; consequently, the nodes have a backward motion along the ecliptic; and in this manner make a complete revolution in 18 yrs. 223 days 7 hours 13 min. 17¾ sec. This period is called the *great lunar year*, because in it we have a recurrence of all the same eclipses.

But the motion of the line of apsides is very irregular. For, though its progress is according to the order of the signs, when

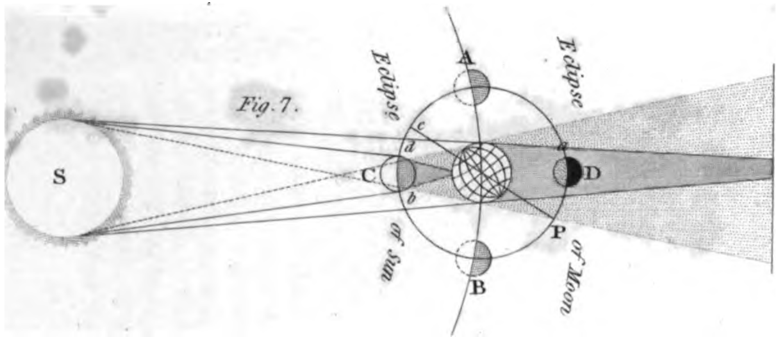


Fig. 7.

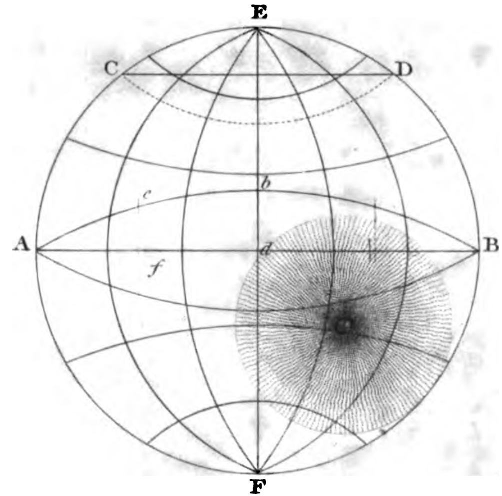
Fig. 8.


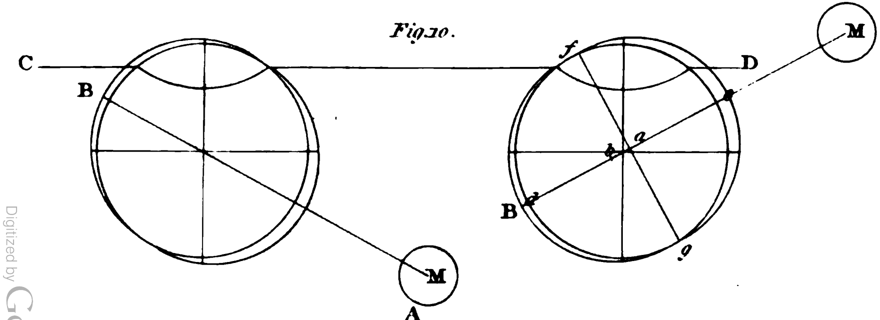
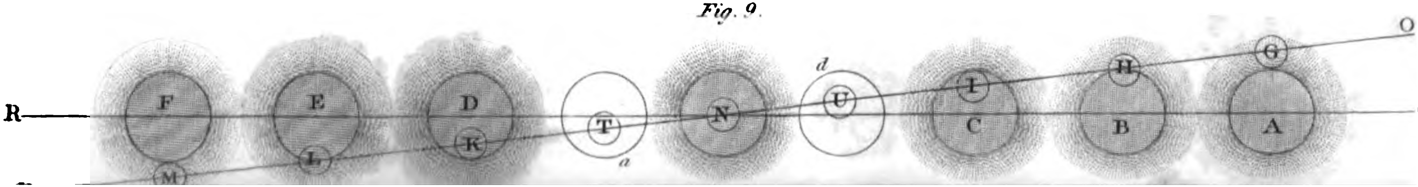
Fig. 10.


Fig. 9.


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it is at or near the place of change; yet, when it is at the quadratures it has a contrary motion. In this latter case, the regress of an entire lunation exceeds the progress; but the progress, when the apsides is in a line with the earth and sun, so much exceeds the regress when the apsides is in the quadratures, as, in a number of revolutions, to occasion the great lunar year above described.

The axis of the moon is inclined to the plane of the ecliptic at an angle of 88deg. 29min. 49sec.; but, to the plane of her own orbit, at an angle of 83deg. 20min. 49sec.; or, the moon's equator is inclined to the plane of the orbit at an angle of 6deg. 39min. 11sec. allowing the mean inclination of the two orbits an angle of 5deg. 9min.

As the axis of the moon is not perpendicular to the plane of her orbit; when at her greatest northern latitude, we can see more of her northern limb, or more of the black spots around the north pole; and when at the greatest southern latitude, we see more of the southern limb, or of the black spots around the south pole. This is called the moon's *libration in latitude.*

From the irregular motion of the moon around the earth, and the uniform motion on her own axis, we at one time see a little more than usual of her western limb; and in the opposite part of the orbit, a little more of the eastern limb. This variation is at the greatest about 7deg. 3min.; but it vanishes when the moon is near the apsides. It is called the *libration in longitude.*

A third libration arises from more of the western limb being seen at rising, and more of the eastern at setting:—this is called the *diurnal* or *parallactic libration.*

There are a great many other irregularities in the moon's motion; so that, in finding the longitude by this luminary, there are about 30 equations to be applied to its mean longitude before the true is obtained; and nearly 24 equations for its latitude and parallax, which render the mere finding of the moon's true place in the heavens a work of considerable labour.

2. PHASES OR CHANGE.

The planes of the orbits of the earth and moon being so near a coincidence, that is, making a mean angle of only 5deg. 9min. —it is evident, that the moon must in every revolution come almost in a line between the centres of the earth and sun. And

as only that half of the lunar orb next the sun is enlightened, when the moon is at this conjunction, the whole dark side must be towards the earth; consequently, the moon must be invisible: this is called change or new moon: (vide C. Fig. 7.)

Though the moon always keeps the same side towards the earth; yet, in one revolution, all parts of the lunar orb are presented to the sun. The motion of the moon, like that of all the planets, is from west to east; and proceeding along the signs at the daily mean rate of 13 deg. 10 min. 35 sec., she soon passes so far to the left of the conjunction, that a part of the enlightened hemisphere is composed of that half of the orb presented to the earth: consequently we see it with two sharp horns. At the end of about 7 days 9 hrs. 11 min. the moon will have performed one quarter of a lunation, and will be at B. We shall, therefore, see one half of her enlightened side, which has the appearance of a semicircle. The right or west side has now the sun vertical, and the left or east side, being directly opposite, is in midnight. This is called the *first* quarter.

Having passed this point, the moon no longer retains the apparent semicircular form, but begins to swell from the centre. This appearance is called *gibbous*; and it increases till the disc is perfectly round; the whole of the moon's enlightened side being towards us. The earth is now in a line between the sun and moon;—the moon therefore is at D, and is said to be at *opposition*: this is the time of *full moon*.

The moon now becomes gibbous on the right or west side; and continues waning till she arrive at A, the *third* quarter, when the appearance of a half circle is again presented: the left or eastern side having the sun vertical, and the right the obscurity of midnight. After which, the enlightened part of her disc diminishes till she finally disappears for another change.

The last sight of the old moon may be had near the eastern horizon among the rays of the rising sun; and the first sight of the new moon, near the western verge of the sky amidst the sun's setting beams. When the moon is at the utmost point of southern declination, she is, when on the meridian at London, only 9 deg. 11 min. above the horizon; but when at the greatest northern declination, she has, when on the meridian, an altitude of 66 deg. 41 min.: hence, this luminary sometimes appears almost over our heads, and a fortnight after seems scarcely to rise above the southern horizon.

3. LUNAR DAY AND NIGHT.

In one lunation it will be seen that all parts of the moon's surface will have been towards the sun once, and only once; so that the *lunar day and night* must be equal to more than 29½ of ours.

At new moon, the side towards the sun will have noon, and the side directly towards the earth, midnight. At the first quarter the former place will be at sun-set, and the latter at sun-rise; it being 6 o'clock in the evening with the one, and 6 in the morning with the other.

At full moon, the part which was towards the sun at change, and, consequently, had noon-day, will be at midnight; and that which has midnight at change will have noon-day, being both towards the earth and sun.

At the third quarter, the side towards the earth will have sun-set, or 6 o'clock in the evening; and the opposite sun-rise or 6 o'clock in the morning: and when the moon arrives at change, the day will be completed.

4. THE EARTH AS VIEWED FROM THE MOON.

The earth is to the moon, with respect to light, what the moon is to the earth; but it will be seen that only one half of the moon receives benefit from the earth's reflected light.

Presenting the same side continually towards the earth, half of the lunar inhabitants, (as probably the moon is inhabited), will never see the earth; but will be near a fortnight in total darkness, having light neither from sun nor moon. Should a Lunarian, whose usual place of residence is on the farther side of the moon, have his curiosity excited by the marvellous tales of travellers from this side of the lunar surface, respecting a large body, more than thirteen times the apparent size of the sun, shining almost continually in the midst of the skies; before he can be convinced of the truth by occular demonstration, he will have to make a journey towards this side. And, should he come as far round *his* world as to that place to which this said wonderful luminary is vertical, at the time when we have new moon, he will see it, apparently, *thirteen* times as large as the full moon appears to us. Not always tenaciously keeping the same side towards him, or rising or setting, as the moon does to us, but presenting all its sides in the course of 24hrs. 50min.

28 sec. of our time, and never losing itself in obscurity for almost fourteen of our days; and, even when most obscured, presenting a luminous ring occasioned by our 18 deg. of twilight; or a beautiful crescent on one side, on account of the angle made by the plane of the orbits.

Nevertheless, during the above period, or in the time of the former half of our lunations, this luminary will wane like the full moon. After about seven of its revolutions only one half of its enlightened disc will be seen; and when about 14 are completed it will be at change,--exhibiting only the luminous ring or crescent. After which it will appear horned, in some respects not unlike the new moon, and will wane for about some fourteen revolutions more, when it will be again circular and at full. The Lunarians' full moon is therefore our change;—and their change is our full.

5. ECLIPSES.

If the plane of the earth's orbit and that of the moon exactly coincided, as in Fig. 7, in every lunation we should have two eclipses. When the moon is at change or C, her shadow would fall upon the earth, and hide the sun from us; this would be an eclipse of the sun, or, more properly speaking, of the earth. And when the moon is on the opposite side of the orbit at D or full, the earth would be in a line between the moon and the sun; and the moon, having no light but what is borrowed from the sun, would now, being immersed in the earth's shadow, be totally eclipsed.

The young astronomer will readily perceive that every *solar* eclipse must happen exactly at the change of the moon; and every *lunar* eclipse precisely at full moon; and that the solar eclipse must commence at the western limb or right side of the sun, (*d* Fig. 7); and the lunar at P or eastern side of the moon.

But as the plane of the moon's orbit makes an angle of 5 deg. 9 min. with the plane of the earth's orbit, eclipses at every lunation cannot take place. Suppose, for instance, that the nodes or points where the moon crosses the ecliptic, be at the quadratures B and A; that at the third quarter A, being the ascending node; then, when the moon arrives at the place of change, she will be 5 deg. 9 min. on this side of the ecliptic or above the sun. This angle will elevate the moon's shadow about 20,000 miles above the plane of the earth's orbit; consequently, about 16,000

miles above the north pole. So also when the moon comes to the place of full, having in the mean time passed the descending node at B, she will be 5 deg. 9 min. beyond the ecliptic, or her shadow will pass 16,000 miles below the south pole; so that, in neither case can an eclipse occur.

Notwithstanding this angle, were the nodes at full and change we should have eclipses exactly the same as if the two planes coincided; and were the nodes stationary, we should every lunation have a recurrence of the same eclipses. But they are not stationary.

It is found by observation that when either of the nodes is within 15 deg. of either side of the place of change, a solar eclipse at that conjunction must take place. But this limit of the eclipses chiefly refers to the two luminaries at apogee; that is, when the earth (July 1st) is at the aphelion point of its orbit, being at the greatest distance from the sun; and the moon is at that part of the orbit at the greatest distance from the earth. But when the lines of apsides are reversed—that is, when the earth, (December 31st) is at the perihelion, and the moon's perigee is at the place of change, an eclipse will take place at that conjunction, though the node is not nearer to the conjunction than 21 deg. Therefore, between 15 and 21 deg. there may or may not be an eclipse; this space on each side, is called the *solar ecliptic* limit. The *mean* distance of the solar ecliptic limit, on each side of the conjunction, is fixed at 17 deg. 21 min.

The least lunar ecliptic limit is at 7 deg. 47 min. on each side of the opposition; within which, the moon crossing the ecliptic, there must be an eclipse; but when the lunar perigee is here there may be an eclipse, though the node's distance from the opposition be 13 deg. 21 min. The *mean* distance is 11 degrees 31 min.

Now as the nodes have a backward motion along the signs, making a full revolution of the ecliptic in 18 yrs. 223 dys. 7 hrs. 13 min. 17½ sec. they will retrograde about 19 deg. 20 min. in a year. Suppose, then, the nodes at the points *e* and P Fig. 7, just beyond the mean solar ecliptic limit; that at *e*, the ascending node; then, were the earth stationary, it is evident that an eclipse could not occur till the nodes had retrograded to *a* and *b*; which would require between 7 and 8 years. But as the earth is not stationary, making an entire revolution in its orbit every year, at the end of half a year, the other part of the moon's orbit D will be towards the sun, instead of C:—consequently in the intervening time, the node P will have been at the place

of new moon; and as the solar ecliptic limit from *d* to *b* is 34 deg. 42 min., the earth would be above 35 days in passing it. Now, as the moon makes a revolution in little more than 29½ days, it is evident that there must in every year, be solar eclipses. It is possible, also, that there may be two solar eclipses in two successive lunations; but this can very rarely occur: solar eclipses are generally at opposite seasons of the year. However by reason of the retrograde motion of the nodes the interval between them is between 9 and 10 days less than half-a-year—or about 173 days.

The number of eclipses, annually, is generally 4; and as the moon is as long beneath the horizon as above it, there will be only two visible;—one of the sun and another of the moon. But as many as 7 eclipses may occur in one year; 5 being of the sun, and the remaining lunar ones will in this case be total. And it is possible that only 2 solar ones may happen. The space of the solar ecliptic limit is to that of the lunar nearly as 3 to 2;—and the number of solar and lunar eclipses bear nearly the same proportion to each other; but as the lunar are visible in all places where the moon is above the horizon, and the solar not so; we, consequently, see more lunar than solar eclipses.

The course of the moon's shadow over the earth in a solar eclipse, is from west to east; but if the moon is at the ascending node, it will incline towards the north; and if at the descending node, the shadow will decline towards the south.

6. SOLAR ECLIPSES.

THE eclipses of the sun are total, annular, and partial. The partial happen when one of the nodes is within the ecliptic limit, but not nearer the conjunction than 8 or 10 degrees; for then, they would be either annular or total; yet, all solar eclipses are only partial to the greater part of the earth. A total eclipse is when the whole of the sun's disc is hid by the moon from a certain portion of the earth's surface; and an annular one depends upon the following circumstances.

Annular Eclipses.—When the earth is at the aphelion or at the greatest distance from the sun, the sun appears less than when the earth is at the perihelion or least distance. The same is the case with the moon: she appears less at the apogee than at the perigee. A line across their centres is called their apparent diameter, and is estimated in minutes and seconds; or is

considered as extending over so much of the whole circumference of the sky. These apparent diameters are as follows:

Sun at the apogee or greatest distance	31 min.	45 sec.
Do. at mean distance	32 -	15 -
Do. at perigee or least distance	32 -	45 -
Moon at apogee	29 -	22 -
Do. at mean distance	31 -	23 -
Do. at perigee	33 -	24 -

Now, should the node be at change, so that we may expect the moon to pass over the sun's centre, while the earth is at perihelion, and the moon is at apogee, the apparent diameter of the sun will exceed that of the moon by 3 min. 23 sec.; therefore when the moon is directly over the sun's centre, there will be a luminous ring all round. This is called an annular eclipse.

From inspecting the above table of apparent diameters, the young astronomer will perceive, that the eclipse will be annular when the luminaries are both at their mean distances. And knowing the position of the lunar line of apsides, and the earth's place in the orbit, he will readily determine whether an eclipse will be annular or not.

Total Eclipses.—When the earth and moon are so situated in their orbits, that the apparent diameter of the moon exceeds that of the sun, and the node is within 8 or 10 deg. of the place of change;—then the eclipse will be *total.*

The sun being in reality so much larger than the moon, occasions the moon's shadow to be in the shape of a cone; the base being at the moon and the apex towards the earth. Now this conical shadow is found to be, in length, nearly equal to the moon's mean distance from the earth. Therefore, when the moon is at more than the mean distance from the earth no eclipse can be total; for if the node be within the limit of total eclipses it will be annular. But when the moon is at less than the mean distance from the earth, the end of the cone will pass over the earth; and, therefore, wherever this shadow falls there will be a total eclipse.

But as the greatest apparent diameter of the moon is only 33 min. 24 sec.; while that of the earth, as viewed from the moon, is 120 min.; the attenuated point of the moon's conical shadow can extend over a very small portion of the earth's surface. Total eclipses must, therefore, be very *local.* Fig. 8 will

represent a total eclipse, (that is, a solar eclipse) as seen from the moon.

The black spot is the conical shadow; and represents as large a total eclipse as can possibly happen. Its diameter on the earth's surface extends about 180 miles, while the earth's disc or surface extends a diameter of nearly 8,000. This black spot or umbra, as it is called,—will be seen from the moon passing over the earth's disc, with a velocity nearly double that of the earth's revolution on its axes, or at the rate of about 30½ miles per minute.

When the node is at the place of the new moon, the umbra will pass over the earth's centre; should the ascending node be at about 5 or six degrees before the moon comes to the change then the umbra will pass over the latitude of England; and if the luminaries are above the horizon we shall have a total eclipse. Should the node be about 10 degrees from the place of conjunction, the umbra will pass near the north pole.

In annular eclipses there can be no black spot or umbra; the imperfect shadow that surrounds it, called the *penumbra,* will be the only one seen;—and its breadth will be equal to the apparent diameters of the sun and moon, or, it will extend a diameter upon the earth's surface of about 4,900 miles.

The last total eclipse of the sun that occurred in England was in the year 1715; and it is the only one that has happened for six centuries; nor will there be another for two centuries to come.

Partial Eclipses.—Though total eclipses are so very local, yet the moon will hide a large part of the sun from the earth, for a considerable distance on all sides of the umbra or total eclipse. Near the umbra a little of the sun's edge will be seen; at a greater distance a little more; till we advance as far from the umbra as the sum of the apparent semidiameters of the sun and moon, which at a mean is about 32 minutes. Hence, the partial eclipse will extend on all sides to a distance of 32 minutes, or to a diameter of 64 min.;—which is more than the earth's semidiameter, as seen from the moon, by about 900 miles as stated above. But by reason of only a small part of the sun being seen near the umbra, and a like part being only hid near the extremity of the penumbra, this imperfect shadow will be the densest towards the centre.

From inspecting Fig. 8, it will be seen that part of the penum-

bra may fall upon an edge of the terrestrial disc, when the umbra will be a long way from it; and therefore many partial eclipses may happen without being any where total. All the eclipses, that take place when the node is at more than two-thirds of the ecliptic limit from the conjunction, will be partial, and must take place about the polar regions.

A total eclipse can only continue at one place about 5min. 17sec.; indeed, the sun can only be completely immersed in the moon's shadow about 4 minutes. An annular eclipse may continue about 12min. 24sec. The whole, that is, including each side of the penumbra, never continues more than 2 hours. But from the time of the penumbra's first touching the earth, to the time of its finally quitting it in a central eclipse, is about 5½ hrs. When the eclipse is not central, the earth cuts the lunar shadow obliquely, so that the umbra, as shewn Fig. 8, will be elliptical: hence, the duration of total eclipses will vary from 5min. 17sec. to 7min. 58sec.

7. LUNAR ECLIPSES.

THE eclipses of the moon are total and partial; and they take place at the full moon, when the node is either at, or within the mean ecliptic limit, that is, within 11deg. 34min. of the opposition.

The earth's shadow like that of the moon is conical; and is calculated to extend about 800,000 miles; so that, it must be diminished about a quarter where the moon passes through it in an eclipse. In Fig. 9 are represented sections of the earth's umbra and penumbra with the moon passing through them. Q R is a part of the ecliptic; and O P a part of the moon's orbit, making an angle with the ecliptic of 5deg. 9min. N is the descending node; so that the figure may be said to represent seven lunar eclipses;—one central, two total, and four partial.

The breadth of the penumbra is equal to the sun's apparent diameter; and, as this is nearly equal to that of the moon, the whole of the moon's disc may be immersed in the penumbra, before any of it enters the umbra. The moon during an eclipse is not invisible as at change; but assumes a copper coloured appearance, occasioned by our 18deg. of twilight, wherein the sun's rays are refracted by the earth's atmosphere into the umbra, and produce this effect. During a lunar eclipse the Luna-

rians will have the same phenomena that we have in a solar eclipse; for to them it is a solar eclipse.

The duration of a central eclipse varies from 3hrs. 37min. 26sec. to 3hrs. 57min. 26sec.: the moon's motion being the slowest when she is at the greatest distance from the earth. But her whole disc cannot be totally hid in the umbra more than 1¾ hrs.;—and the time from the moon's first touching the penumbra to her finally quitting it never exceeds 5½ hrs.

The discs of the sun and moon are supposed to be divided into digits or twelve parts; so that, in speaking of eclipses, it is usual to say, so many digits of the luminary's disc are eclipsed. But though the lunar disc only contains 12 digits, yet the moon in a total eclipse may be 23 digits eclipsed.

In Fig. 9. A B C N D E F, are so many sections of the earth's umbra, with the moon touching some and passing through others, representing so many partial and total eclipses. When the opposition is at A, the moon G only just touches the earth's umbra, without being eclipsed. At H six digits are eclipsed. At I twelve digits; at U eighteen digits, the moon being a semidiameter below the nearest edge of the umbra. At N she is centrally eclipsed, which cannot exceed 23 digits. The same may be observed when the opposition is at the sections T K L M.

From what has been said of the conical shape of the shadow of the earth and moon, it will appear, that if the moon were at a greater distance from the earth, we should have no eclipses. Hence it is, that the inferior planets pass over the sun's disc unperceived by the naked eye. And the primary planets, for the same reason, never eclipse each other:—the earth's shadow does not reach Mars by 50 millions of miles. This proves how much larger the sun is than any of the planets. For if he were less, the conical shape of their shadows would be reversed; and if he were in magnitude no more than equal to them, the shadow would be cylindrical. It should be also observed that while the umbra converges to a point, the penumbra diverges till its obscurity vanishes.

A Table shewing the longitude of the moon's ascending node for the beginning of each year for 20 years to come, reckoning along the signs from the first point of Aries.

Year.	S. deg. min.	Year.	S. deg. min.	Year.	S. deg. min.
1824	9 19 0	1831	5 3 40	1838	0 18 14
1825	8 29 40	1832	4 14 7	1839	11 28 55
1826	8 10 20	1833	3 24 57	1840	11 9 33
1827	7 21 0	1834	3 5 37	1841	10 20 12
1828	7 1 38	1835	2 16 17	1842	10 0 52
1829	6 12 18	1836	1 26 54	1843	9 11 32
1830	6 22 58	1837	1 7 34	1844	8 22 10

As the nodes are directly opposite each other or six signs apart, and as they retrograde annually 19 deg. 20 min. their places on any particular day of the year may be easily found; and knowing the sun's place in the ecliptic, which may be easily found from the following statement, we may at any time ascertain whether either of the nodes are within the ecliptic limits; and, consequently, whether an eclipse will take place at any particular conjunction or opposition. The sun enters the different signs as follows:—♒ about January 20th. ♓ February 18th. ♈ March 20th. ♉ April 20th. ♊ May 21st. ♋ June 21st. ♌ July 23rd. ♍ August 23rd. ♎ September 23rd. ♏ October 23rd. ♐ November 22nd. ♑ December 21st. Mean place of perigee at the beginning of 1824, 4 signs 1 deg. 47 min. 34 sec.

The following circumstances belong to the calculation of a lunar eclipse, (a solar eclipse is much more difficult). The true time of full moon; the moon's horizontal parallax; the sun and moon's apparent semidiameters; the semidiameter of the earth's shadow at the moon; the moon's latitude; the angle of the moon's visible path with the ecliptic; the moon's true hourly motion from the sun.

8. HARVEST MOON.

As the moon revolves round the earth in an orbit that sometimes makes an angle with the plane of the earth's orbit of 5 deg. 18 min. or with the plane of the earth's equator of 28 deg. 45 min. her regular time of rising will be thereby considerably affected.

The moon completes a revolution round the earth in rather more than 29½ days; and proceeds at the daily mean rate of 13 deg. 10 min. 35 sec.; and as 15 deg. are equal to an hour, she would on this account, if she moved in the plane of the equator, be about 50 min. later of rising each succeeding time. But as

the moon is only sometimes upon the equator, sometimes 28 deg. 45 min. south of it, and at other times the same distance to the north of it, her time of rising will considerably vary from this true time of 50 min.

This case is similar to that first stated under "Equation of Time," Chap. II. s. 11. so that, the moon rises most regularly when near the equator and at the tropics, but especially at the latter. When her northern declination is the greatest, and she is passing the signs Leo and Virgo—she will for 6 days together, in that part of the ecliptic, daily exceed her true time by 29 min.; and when she has passed the equator at Aries and is proceeding northward, the whole time of variation for 6 days together may not be much above two hours;—whereas her true time would be 5 hrs. 12 min. 48 sec.

All this takes place in every lunation; but it so happens, that the moon's rising in the last mentioned circumstance only attracts particular attention when at *full*. For in winter when the moon passes Aries she is about the first quarter and rises at noon; when at the same sign in spring, she is at change and not seen; and in summer, at her last quarter and rises at midnight; but in autumn, being at full, she rises at sun set. Now this can only take place when the sun enters Libra at the autumnal equinox, for we never have full moon but when the sun and moon are in directly opposite signs; and as it is generally the time of harvest, so this lunation is by way of preeminence stiled the *The Harvest Moon*. As superstition has it, "The moon kindly hastens the time of her rising for the convenience of the husbandman."

However the harvest moon greatly depends upon the situation of the lunar nodes; in order that she may in this lunation have the greatest northern declination. And to produce this effect, the ascending node must be at or near the first point of Aries; should the descending node be in this situation, the moon, in this lunation, when she has passed the first three northern signs will be only 18 deg. 9 min. north of the equator, instead of 28 deg. 45 min.; consequently, in these six days mentioned above, when her time of rising varied only about two hours, it will vary above *three* hours; and her light will be therefore of less importance to the husbandman.

In the years 1820 and 1821 the harvest moon was the most beneficial, the ascending node being then near the first point of Aries. By inspecting the table of nodes given in the last sec-

tion, it will be seen that the descending node will enter Aries in 1830; therefore, in that year the harvest moon will be the least beneficial: her importance varying, through all the intervening years, with the retrograde motion of the nodes that make a revolution in about 19 years.

As the moon comes, at a mean, 50 min 28 sec. later every day to the meridian, if we multiply this by the days of her age, we shall have nearly the number of minutes P. M. when she comes to the meridian on any particular day;—which is called her *southing*.

9. TIDES.

TIDES are the well known periodical flux and reflux of the sea; and are caused by the attraction of the sun and moon. But the attraction of the moon is to that of the sun as 4½ to 1; and therefore the tides, in common language, are said to depend upon the moon.

As the moon comes to the meridian on each day later by 50 m. 28 sec. this elevation of the waters will pass all round the earth in the space of 24 hrs. 50 min. 28 sec. and as the moon's attraction only extends over half the earth's surface, or as far as there is moonlight; consequently, as the moon passes forward, and ceases to attract the waters, they will rush back again, and be collected into a heap in the centre of the opposite hemisphere; making thereat another tide; which for the sake of distinction we shall call the *tide of reaction*.

The principle force of the moon's attraction is in the line of direction, that is, the line M B Fig. 10. joining the centres of the sun and moon. The highest point of the tides will therefore always be (or rather should be according to the present mode of explaining the phenomena of tides) in the plane of the moon's orbit; and though the tide of attraction *e* is somewhat greater than the tide of reaction B *d*; yet, when the moon is in the southern signs or at A, we, who live in the northern hemisphere, will have the tide of reaction greater than the tide of attraction; and the reverse when the moon is in the northern signs. This will appear more plainly from inspecting Fig. 10, where C D represents the line of tides that sweep England.

The same takes place in the tides caused by the sun. And when the moon is at full and change, the powers of their attraction, or the reaction of the waters are united, and produce a

large tide called the *Spring tide.* The sun is calculated to raise the waters about 2 feet and the moon about 9 feet; and therefore a spring tide will have an elevation of 11 feet.

But at the first and third quarters while the moon is on the meridian the sun is at the horizon, that is, rising or setting, and and in this case their powers are separated, pulling in a direction at right angles to each other; and though in this case we have no observable tide caused by the sun; yet the sun diminishes that caused by the moon, so that we have a tide of only 7 feet elevation, called the *neap* or low tide.

Now as the orbits both of the earth and moon are elliptical; and the reason that the moon attracts the waters more than the sun, is owing to her greater proximity to the earth; consequently, they will both have more power when at the perigee, or in that part of the orbits nearest the earth, than when in any other part. It was calculated by Newton, that if the moon were at half the present distance from the earth, the tides would be eight times greater than we now have them. Hence we have the greatest spring tides when the moon, at full or change, is in the perigee; and the least when in the apogee. Now as there is but a fortnight between these two points, there, consequently, cannot follow two large spring tides, one at the full and the other at the change of the same lunation. But on the contrary, it is evident, that when the spring tides at change are the largest, the moon being at the perigee, those at full must be the least: occurring a fortnight after when the moon is in the apogee.

But the highest tides of all are at the equinoxes; for then the sun is nearer to the earth than in summer; and the two powers are more closely united, acting in the same direct line. However the spring tides vary every year by reason of the progressive motion of the moon's line of apsides. Should the moon therefore at full or change be in the *perigee*, near the equinoxes, there will be a large spring tide, such a one as cannot again occur till the apsides have made either a half or a full revolution, which must be between 4 and 5, or 8 and 9 yrs.

The above are the general laws of the tides; but there are many impediments to their regular course. For, though the greatest influence of the moon's attraction is in the line of direction M B Fig. 10; yet, the largest swell will not be at that place till two or three hours after the moon has passed its meridian. The momentum is indeed given along this line; nevertheless it must be some time before the waters are collected into a heap.

This is easily exemplified by drawing a wooden bowl quickly across the surface of a vessel of water; when the swell will be seen, not to accompany the bowl, but to follow at some distance. For the same reason, the highest spring tides are not on the day of full or change, but about two or three days after. Hence, it is evident, that if the attraction of the sun and moon were to cease, the tides would continue for some time to ebb and flow, as the waves put in motion by a storm continue to roll long after the wind has ceased.

Neither are the first flowings or the last ebbings of the tides after equal intervals of time at the same place. For as the sun causes a tide of two feet, this will raise the waters a certain height, though the moon be at the horizon, (for instance in the first quarter;) and though this does not, by reason of the moon's tide so quickly following, appear to be a different tide; yet it will make the tide on that day rise earlier than might otherwise be expected. But when the moon is at the third quarter, instead of the solar tide accelerating the flow of the lunar, it will retard its ebb; and consequently the time of low water will be later at that place.

Were the earth's surface covered regularly all over with water the swell would be regular, as it appears in Fig. 10, on each side of the earth; and as the tides both of attraction and reaction move round the earth in 24hrs. 50min. 28sec. there would, perhaps, be little or no change of elevation at the points *f* and *g*; and not much at the poles. But as only about two-thirds of the earth's surface are covered with water, and these are intersected by continents, and interspersed with islands, the tides are very much diverted from their regular course.

The waters in the Baltic, Mediterranean, and other inland seas are so confined from north to south, and in other directions, that the tides are very inconsiderable. But in the Atlantic, where the attractions of the sun and moon have a long sweep, and the waters are unconfined towards the poles, there is a very large swell on the eastern coasts of America; and, of course, a great depression on the western coasts of Europe and Africa, with a corresponding fall on the former coasts, and rise on the latter, caused by the reaction. But as the vast Pacific ocean is still larger than the Atlantic, the tides are higher round that immense ocean.

Hence, it is evident, that tides must vary very much in different places; and that from the general principles of their cause,

no regular rule can be given for their passage through straits and channels, along winding shores and up narrow rivers. Experience and long observation are, therefore, the only safe guides; and accordingly, from observations, made in all the principal ports in the world, tide tables have been constructed, shewing the time of high water at each particular place, in every day of the moon's age.

In the open sea the tide is seldom elevated above a few feet, though it is sometimes powerfully increased by the wind, especially the equinoctial gales. But by reason of its momentum, it rises much higher against shores, and in straits and rivers. At London the spring tides rise 19 feet; at Brest 20 feet, at Bristol 30, at Chepstow 40, at St. Maloes 50, and at Annapolis Royal in the Bay of Fundy sometimes 100 feet. Among the Orkneys the sea in a storm will occasionally rise 200 feet perpendicularly. In the centres of the Atlantic and Pacific oceans, the tide is said not to rise above two or three feet: hence, we must conclude that the great elevation it attains against the shores of continents is occasioned by its momentum. On all these occasions, where it rises to the greatest height, we find the wave entering the wider end of a channel, that lies in the line of the tide's direction; and by the channel regularly contracting its sides, the wave is wedged in, and the water is thus pressed to a greater elevation. On the contrary, when the mouth or trunk of the channel is at right angles with the course of the tide, or the wave enters the narrow end, then, the elevation of the water is very inconsiderable. See Chap. V. s. 5.

Fig. 11.

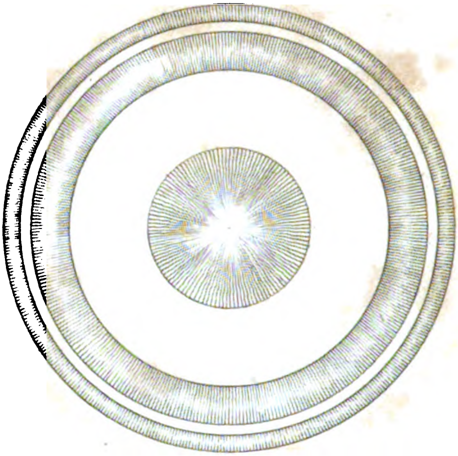


Fig. 12.

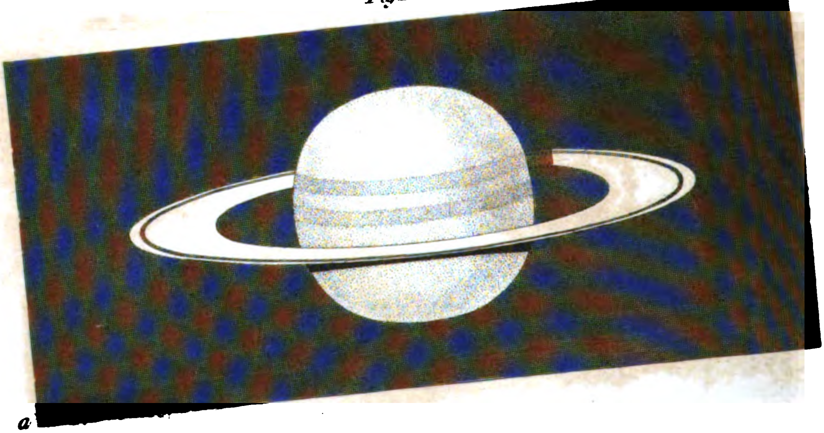
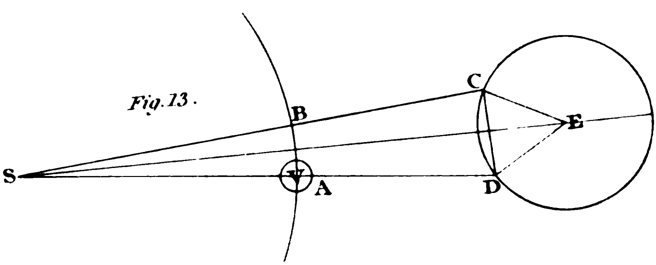


Fig. 13.



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CHAP. IV.

The Heavenly Bodies Described.

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1. The Sun. 2. Mercury. 3. Venus. 4. The Moon. 5. Mars. 6. The Asteroids 7. Jupiter. 8. Saturn. 9. Uranus. 10. Planetary Motion. 11. How the Distances of the Sun and Planets have been Determined. 12. The Fixed Stars. 13. Sir William Herschel's Description of the Universe.

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1. THE SUN.

The sun was supposed by Sir Isaac Newton to be a solid globe of fire, so hot as to afford, at the distance of 95 millions of miles, the light and heat we daily experience from his beams. But as that great philosopher was enabled to make his wonderful discoveries, from the information which a small telescope afforded him, subjecting his own observations and those of all who had gone before him to the unerring laws of mathematical demonstration; so succeeding philosophers, having glasses much exceeding his in magnifying power, together with his discoveries to begin upon, and his rules of demonstration to direct them, have, consequently, since his time, much extended the science of astronomy; and have obtained such results, with respect to the nature of the sun, as warrant their widely differing from him in opinion. The theory now supported, and which seems to be well established by the discoveries of the late Sir William Herschel, is, that the sun is a solid opaque globe, adapted to animal life, but surrounded with a very extensive and luminous atmosphere. See Chap. XIV. s. 4.

The sun when viewed through a telescope seems, at times, far from uniformly luminous; having sometimes black spots on his surface. They first appear on the eastern limb, and cross over the disc to the western limb. At the end of about 13¾ days from their first appearance they vanish; and are invisible for about 13¾ days more; when, if they are not in the mean time dissolved, they re-appear on the east. From this circumstance it has been discovered, that the sun has a rotary motion on his own axis; and that he performs a revolution in the space of 25dys. 10hrs.

The spots do not seem to pass over the disc in a uniform and parallel direction. Their motion is generally from east to west. At opposite seasons, namely, at the beginning of June and December, they are rectilineal; and cut the ecliptic nearly at an angle of 7deg. 30min. Between June and December they form a convex upward curve: the greatest curvature being in September. In the opposite six months they form, by the same series of changes, a concave curve downwards. From these circumstances it has been deduced, that the sun's axis is inclined 7deg. 30min. from perpendicularity with the plane of the ecliptic or earth's orbit: his north pole pointing in the direction of half way between the constellation Lyra and the polar star.

Previously to the days of Herschel, these black spots amused and perplexed philosophers very much. His opinion was, that the solar sphere has mountains on its surface not less than 300 miles high; and that on their top, the atmosphere, being by some means disturbed, becomes so thin as to permit us to have a glimpse of the sun's opaque body.

It is observed of these spots, that after they disappear the places where they were become brighter than the rest of the solar disc; that the longer they are in forming, the slower they are in dissolving; and that their sudden appearance is succeeded by an equally sudden disappearance. Two spots will sometimes unite; and at other times one will divide into two, which will recede from each other with considerable velocity. Their sizes are various. Some are imperceptibly small; and others as large as the whole continent of Europe, Asia and Africa. In the year 1779 there was one visible to the naked eye, of not less than 50,000 miles diameter. None of them ever continued longer than 70 days; while some form and dissolve in a few hours. The sun is sometimes free from them, but was never known to be so for a whole year together.

A little after sun-set in the month of March, and a little before sun-rise in the month of September, at which seasons the earth cuts the plane of the sun's equator, a very remarkable phenomenon is seen, called the *Zodiacal Light*. It is supposed to be part of the sun's luminous atmosphere, flying off in the plane of his equator, by reason of his great velocity or centrifugal force. It has a pyramidal form with the sun for its basis; and a luminous appearance resembling the *aurora borealis*. It is much brighter and more extensive in some years than in others: extending an angle from the sun that varies from 45 deg. to 100 or 120 deg. Its plane cuts the ecliptic at 18 deg. Gemini. The most favourable time for viewing it, is, at the termination of twilight in a clear evening in the earlier part of March, when its axis points in the direction of the star Aldebaran.

The comparative light of the sun, according to Eular, is equal to 6,500 candles at the distance of a foot; that of the moon equal only to one at 7½ feet distance; that of Venus to a candle at 421 feet; and that of Jupiter to one at 1,320:—consequently, was the sun at 131,000 times his present distance, his light would only be equal to that of Jupiter.

The sun is an oblate spheroid, or a little flatted at the poles; his equatorial diameter is above 100 times that of the earth, or 883,246 miles; and therefore the sun is in magnitude 1,384,472 times larger than the earth; but his density is only one fourth of the earth's density, so that, the weight of the sun is only equal to about 337,086 times the earth's weight, or 530 times the weight of all the planets of the solar system put together. A body at the surface of the sun would weigh above 27 times as much as it weighs on the earth; or 1 lb. at the earth's surface would at the sun weigh 27 lb. 14 oz. 15 drs. A body falls to the earth with a velocity of 16 ft. 2 in. in a second of time; but in the same space of time it would move at the solar surface, through a distance of 334 ft. 8 in.

The similarity of the sun to the other globes that compose the solar system, namely, its being diversified with hills and dales; and its rotation on its own axis, renders it more than probable that its surface is inhabited. The supposition of the solar plains being too hot for the accommodation of such living creatures as we are acquainted with, does not rest upon a solid foundation. There are many arguments to prove that the sun's rays only produce heat when they act upon a proper medium; therefore, the sun's surface may be as cool as the earth's. But should it

be as hot as we may suppose from our own experience of the effects of the heat at this distance; yet there may be beings whose organs are adapted to their condition. However, for the present, we leave every one the liberty of making the sun the habitation of whatever kind of *beings* his imagination is able to produce.

2. MERCURY.

MERCURY is a small star of a very bright, white appearance. When viewed through a telescope it appears with nearly the same phases as the moon, according to its position with respect to the sun and the earth: yet, it is never seen entirely round, since the whole of its bright side is never towards us, except when in opposition, at which time it is invisible on account of the solar rays.

This planet never appears with jagged edges, or with dark spots on its disc; hence, it is concluded to have no mountains of any considerable size; and on this account its diurnal motion has not been discovered, though by some it is stated to revolve on its axis in 24 hrs. 5 min. 28 sec. The inclination of its axis to the plane of its orbit is not known, and consequently we know nothing of its seasons.

Calculating on the principle of the sun being a solid globe of fire, this planet's light and heat would be 7 times that experienced on the earth; which in summer is the temperature of boiling water; so that, with a like heat, our water would be all carried off in vapour.

Mercury is more rapid in its motions than any of the planets: its mean progress being double that of the earth, or about 109,442 miles per hour. Its distance from the sun is comparatively so small, that, were it not for the plane of its orbit making an angle with the plane of the earth's orbit double that of any other planet, we should often have it passing over the solar disc. Mercury is never above the horizon more than 1¾ hrs. before or after the sun; and, deducting for twilight, it cannot be seen above half an hour at once; also, on account of its velocity, it does not continue above a fortnight in this position. The best time for seeing it, in the evening is in the spring; and, in the morning, in the latter end of summer or beginning of autumn.

This planet's diameter is 3130 miles, so that, it is in size equal to only a fifteenth part of the earth; but its density

being double the earth's density, their comparative weights are as 7½ to 1.

3. VENUS.

This planet is the most beautiful of all the stars; and when at her greatest elongation is about a quarter of the width of the sky east of the sun, if an evening star; and the same distance west of the sun, if a morning star. Venus performs one of these apparent revolutions in 584 days; so that, the distance of time between the two extremes of her being a morning and evening star is 292 days.

Venus, when viewed through a telescope, exhibits all the phases of the moon. When at her superior conjunction she shines with a full face; but on account of her being at six times the distance of the inferior conjunction, she does not appear so large in the former as in the latter position. When at about two-thirds the distance between the inferior conjunction and quadrature, Venus appears, though little more than a quarter of her enlightened disc is seen, 32 times larger than when seen in some other parts of her orbit; and is sometimes distinguishable by the naked eye in broad day-light. A like apparent increase may be observed in some of the other planets, especially Mars and Jupiter.

Venus is surrounded by a very extensive atmosphere; and bright and dark spots are occasionally seen on her disc. Some astronomers assert that they have discovered mountains on her surface. She revolves on her axis in 23hrs. 20min.; but the inclination of the axis to the plane of the orbit has not been discovered; so that we cannot tell whether this planet has any variation of seasons. A body weighing 1lb. on the earth's surface, would weigh on that of Venus 15oz. 10dr.

4. THE MOON.

The moon is a dark, opaque globe, having no light but what, like the earth, it borrows from the sun, which shines to us by reflection. When the moon is viewed through a telescope, its surface appears diversified with hills and dales. This irregularity is the cause of the light and dark spots observable on its disc by the naked eye. The bright places are the sunny sides of the hills; and the dark their opposite sides or shadows.

Deep cavities or valleys, to whose bottoms the sun-beams cannot penetrate, also diminish the general splendour. For, though a pit or valley has the side farthest from the sun illuminated; yet, the bottom will always appear between it and the sun in considerable obscurity.

It was once supposed that the light and dark places on the moon's surface were sea and land; but those places, that look the most like water, have been found to be full of deep cavities, which circumstance makes this supposition improbable. It was also long contested whether the moon has *any* water on its surface; and, if no water, it was supposed there could be no atmosphere, clouds or rain. The moon is now believed to have an atmosphere of one-third the extent and density of the earth's, but no water.

The best time for making observations on the moon with a telescope, is, when only a part of its enlightened disc is towards us. For then light can be observed travelling over the surface; and, in this case, the line bounding light and darkness appears jagged, occasioned by the sun-beams gilding the mountain tops, while their lower parts continue in comparative darkness. It might be supposed that the mountains would be discovered on the edge; but this is not the case. For, they no more deform the moon's general rotundity, than the little inequalities outside an orange impair its shape. If we examine an orange; those little protuberances and cavities on its rind appear considerable on the part next us; because the rays of vision are perpendicular to the eye; but, looking past the side, especially if that side be towards the light, it will appear quite smooth:- -hence, the lunar mountains are not so easily detected as one might imagine. They were once said to be comparatively much higher than the earth's; but Sir W. Herschel discovered that none of them exceed a mile in perpendicular height; except one which is 1¾ miles high. Its bright side forms the radiating part so conspicuous towards the lower limb.

The disc of the earth, if viewed from the moon, would appear 13 times larger than the moon's disc appears to us; but, as to quantity of matter, the earth is about 48 times larger than the moon. A body on the surface of the moon would weigh only a third part of what it weighs on the earth. The moon's shape is that of an oblate spheroid.

Herschel discovered several volcanoes in the moon. Some of which he saw in a state of actual eruption, ejecting large

quantities of ignited matter. This matter, he observed, had the appearance of burning charcoal in faint daylight, when it has been so long ignited as to be covered with a thin coat of white ashes. The luminous part of a volcano, seen in 1787, he supposed to be not less than 3 miles in diameter. The most favourable time for examining them is soon after change upon the dark part of the disc.

He also describes the lunar mountains as stratified; and Dr. Brewster says, that "Her mountain scenery bears a stronger resemblance to the towering sublimity, and the terrific ruggedness of alpine regions, than to the tamer inequalities of less elevated countries. Huge masses of rock rise at once from the plains, and raise their peaked summits to an immense height in the air, while projecting craggs spring from their rugged flanks and threatening the valleys below, seem to bid defiance to the laws of gravitation. Around the base of these frightful eminences, are strewed numerous loose and unconnected fragments, which time seems to have detached from their parent mass; and when we examine the rents and ravines which accompany the overhanging cliffs, we expect every moment that they are to be torn from their base; and that the process of destructive separation, which we had only contemplated in its effects, is about to be exhibited before us in tremendous reality. The mountains called the Appennines, which traverse a portion of the moon's disc from north-east to south-west, rise with a precipitous and craggy front from the level of the Mare Imbrium. In some places their perpendicular elevation is about four miles; and though they often descend to a much lower level, they present an inaccessible barrier to the north-east; while on the south-west they sink in gentle declivity to the plains."

"The analogy between the surface of the earth and the moon fails in a still more remarkable degree, when we examine the circular cavities which appear every where on her disc. Some of these immense caverns are nearly four miles deep and forty miles in diameter. A high annular ridge, marked with lofty peaks and little cavities, generally encircles them: an insulated mountain frequently rises in their centre, and sometimes they contain smaller cavities of the same nature with themselves. These hollows are most numerous in the north-west part of the moon; it is from this cause that that portion of this luminary is more brilliant than any other part of her disc. The mountainous ridges which encircle the cavities, reflect the greatest quantity of light; and from their lying in every possible direction,

they appear, near the time of the full moon, like a number of brilliant radiations, issuing from the small spot called Tycho."

"It is difficult to explain, with any degree of probability, the formation of these immense cavities; but we cannot help thinking that our earth would assume the same figure, if all the seas and lakes were removed; and it is therefore probable, that the lunar cavities are either intended for the reception of water, or that they are the beds of lakes and seas which have formerly existed in the moon. The circumstance of there being no water in the moon is a strong confirmation of this theory."

5. MARS.

THIS planet is of a red, fiery colour. When it approaches any of the fixed stars they are observed to change their colour, become dim and lastly invisible; which circumstances are accounted for by supposing the planet to have a very dense and extensive atmosphere. When viewed through a telescope it presents phases according to its position, though it is never horned: its disc being always greater than a semicircle.

This planet has more black spots on its surface than any of the primary planets. From these, Herschel discovered that it revolves on its axis in 24hrs. 40min.; and that its axis makes an angle of 59deg. 42min. with the plane of the earth's orbit; and with the plane of its own orbit of 61deg. 18min. The obliquity of its ecliptic to its equator is, therefore, between 5 and 6 deg. more than the earth's; hence, the Martial inhabitants will experience a much greater change of seasons than ourselves. Their proportion of light and heat is less than one half of ours, or as 43 to 100; yet, their summer being double the length of ours, it is supposed their condition will, in many respects, not differ much from our own.

Very bright spots have been observed around the poles of Mars. The bright north polar spot seen in 1781, was supposed to be at about 76 or 77deg. of north latitude:—this supposition was founded on its periodical appearance and disappearance. In the same year a large, bright spot appeared in the southern regions, nearly in the midst of which was the southern pole;—but the spot extended to the 70 or 65 deg. These spots are supposed to be occasioned by the planet's surface being intensely frozen or covered with snow;—but more probably they are of the nature of our aurora borealis.

The magnitude of Mars is less than one-third that of the earth; and its density is only $\frac{7}{10}$ of the earth's density: so that a body weighing 1lb. on the earth would only weigh 5oz. 6dr. on the surface of Mars. The figure of this planet is an oblate spheroid: the equatorial diameter being to the axis as 16 to 15.

6. ASTEROIDS.

The diameters of these according to Sir W. Herschel, are not more than 200 miles; consequently, their discs are too small to have any of their peculiarities detected. It is conjectured, that many such may be circling round the sun in our system; which, by reason of their diminutiveness and their sending forth such feeble rays, have not yet been discovered. Some have supposed them, on account of their differing so much in many respects from the primary planets, to be extinguished comets; and that they are of this origin, as well as perhaps some other of the planets, is rendered extremely probable by the discoveries of Herschel. The eccentricities of their orbits are so great that they cross each others paths with the greatest apparent confusion, see Fig. 1. Their least and greatest distances from the sun with the inclination of their orbits to the ecliptic are as follows:

...	Least Distance.	Greatest Distance.	Inclination.		
Vesta	204,419,947	246,450,053	7deg.	8m.	46s.
Juno	189,792,142	316,968,824	13	3	28
Ceres	242,305,440	283,501,700	10	37	34
Pallas	198,404,567	327,437,913	34	37	8

7. JUPITER.

Jupiter is the largest of all the planets; its cubic magnitude being almost 1400 times that of the earth, but its density is less than a quarter of the earth's density. Like Mars and the other superior planets, Jupiter appears largest when in opposition to the sun; for then it is nearer to us by all the width of the Earth's orbit than when in conjunction; besides, it then turns nearly the whole of its enlightened disc towards us. Jupiter has a bright appearance, but less so than Venus, being when these planets are nearest the earth, at 12 times

greater distance than Venus. The axis is nearly perpendicular to the plane of the orbit; so that the inhabitants of this planet will enjoy little diversity of season. Its figure is an oblate spheroid: the equatorial diameter being to the axis as 13 to 14. Its diurnal rotation is completed in 9 hrs. 56 m.; so that its equatorial parts will be hurled ronnd with a velocity of 26,000 miles per hour. A body weighing 1 lb. on the earth would weigh 2 lb. 4 oz. 8 dr. at the surface of Jupiter.

Jupiter is generally surrounded with broad, thin substances or streaks called *belts;* supposed to be a kind of clouds. They are not permanent: sometimes eight are seen; sometimes only one, and at other times none. They are generally parallel to each other and to the equator, but not always so; for one will sometimes appear to be attracted towards a neighbouring one, and these conjoining make a broad one. The time of their continuance is very uncertain. Sometimes they remain with little alteration for three months; and at other times new ones have been formed and dissolved in a few hours. They appear at times even and well defined; and at other times irregular and broken. Black spots are also sometimes seen among them, by means of which this planet's rotation on its axis has been discovered. Something of this belt-like appearance has been observed on the disc of Mars; but in a much less degree.

Jupiter is attended by four Satellites; which, when viewed on different nights with a telescope of small power, appear to oscillate like the pendulum of a clock: being seen first at one side and then on the other of their primary. At their inferior conjunction, or when passing over the planet's disc, they sometimes appear upon it like dark spots; sometimes like luminous spots; and at other times they cannot be distinguished from the body of the planet. This diversity in their appearance has been supposed by some to indicate a surface composed of land and water; but, perhaps, it may be explained by the different position of the planets and satellites with respect to the earth and sun. In some situations, both the satellites and their shadows may be seen crossing the disc of the primary:—when the former appear as bright spots, and the latter as dark spots. As Jupiter casts a dark, conical shadow behind him in a line with the sun, the satellites are often obscured in it, when they would otherwise be visible from the earth; and at other times they are hid behind the planet when not in its shadow.

These transits of the satellites and their occultations, are very useful to navigators in determining the longitude. The nautical almanac published, as its name imports, expressly for the use of seamen, contains the precise moment of every occultation or transit; and for the convenience of long voyages, it is generally issued three years before they take place. Now if one of the satellites be observed through a telescope, from a ship at sea, to be eclipsed exactly at 8 o'clock; and the sailors refer to the nautical almanack, and find that this occurrence should take place at Greenwich, (the meridian from which longitude is counted), at half past 7; they know that they are in 7 deg. 30 min. east longitude: or, if they find that it should happen at Greenwich at half-past 8 o'clock, they conclude that they are in 7 deg. 30 min. west longitude. The above rule is the same in all latitudes. The eclipse will appear to all parts of the earth, where it is visible, to happen at the same instant; but when considered with reference to the hour of the day, it will vary according to the longitude, reckoning 15 deg. to an hour.

8. SATURN.

SATURN, when viewed through a telescope, is the most beautiful of all the planets. Having not only 7 moons, but also a large double ring, and two belts similar to those of Jupiter. The ring is a thin, broad, opaque substance, encompassing the planet's body without touching it; and is itself of a planetary nature. The plane of this ring is nearly in the plane of all the satellites, having its outer edge towards them, and its inner towards the equator of the primary. Figure 11. would represent this planet and its rings, could we view it in the direction of one of its poles; or, it is a representation of the plane of the rings and planet's equator. The dimensions are, according to Herschel, as follows:

Diameter of the planet	77,680 miles.
Inner do. of smaller ring	146,345 -
Outer do. do.	189,393 -
Inner diameter of larger ring	190,248 -
Outer do. do.	204.883 -
Dis. of inner ring from the planet's surface	34,232 -
Breadth of inner ring..................	19,024 -
Space between rings	2,927 -
Breadth of outer ring	7,317 -

This planet never appears to us as represented in Fig. 11; or the ring being always parallel with itself *i. e*, its situation in one part of its orbit being continually parallel to that of any other, and making an angle with the ecliptic of 31deg., the edge, is always either partially or altogether towards us. The edge of the ring is so narrow that it does not reflect any light; so that when it is towards us the ring seems to disappear. At this time the planet appears quite round with a line across its middle. A little after, when the eye is partly to one side of its edge, the shadow of the ring is visible on the planet's surface; and in about 7 years afterwards the largest quantity of the ring is seen, when it seems to have an oval shape as represented Fig. 12. Thus the ring disappears twice in every revolution of the planet: or, once every 15 years. It was invisible in the beginning of the year 1819.

The ring, when viewed through the most powerful telescopes, appears nearly as bright as any part of the planet's disc; presenting in some degree the appearance of an immense luminous cloud, studded with brilliant spots of different size and splendor, and disposed at various distances from each other. By some it has been supposed to consist of a vast number of satellites disposed so as to present, by reason of their proximity, the appearance of one compact body. The two belts, also, of Saturn appear to be of much greater density than those of Jupiter, and are supposed to be permanent. They are parallel to the outer edge of the ring, and probably of the same nature as the ring itself.

Saturn revolves on its axis in 10hrs. 16min; and the rings are also found to revolve on their own axis, which is perpendicular to their coinciding planes, in 10hrs. 32min. The planes of the rings, which are also coincident with the planes of the planet's equator, make an angle with the plane of the orbit of 30deg., so that, Saturn's change of seasons is considerably greater than ours. The opposite seasons are nearly 15yrs. apart; and one of his years is equal to about 30 of ours. The magnitude of this planet is 1000 times that of the earth, but its density is only one fifth; so that its weight, independent of the rings, is only 200 times that of the earth's weight. One pound on the earth would weigh 1lb. 4dr. if removed to the surface of Saturn. Its equatorial diameter is to its axis as 11 to 10.

The light of this planet, on account of its great distance, is pale and feeble; but Saturn has a very extensive atmosphere

reaching, as is supposed, to the inner ring; and as the ring reflects a light similar to the planet itself, it is reasonable to suppose that it has an atmosphere of its own. Saturn's light and heat, on the principle of the sun being a globe of fire, is only one-hundredth part of what we experience.

9. URANUS, HERSCHEL, OR GEORGIUM SIDUS.

THIS planet was discovered by Sir William Herschel on March 13th 1781. In honour of his late Majesty George III. he called it "Georgium Sidus," or the Georgian Star; foreign astronomers called it Herschel in honour of its discoverer;—but it is now generally known by the name of *Uranus*. Sir I. Newton once saw it, and has left records of its being a planet; but he lost sight of it before he ascertained its motion. It appears to the naked eye no larger than a star of the 6th or 7th magnitude; and is therefore seldom seen without a good telescope. The plane of its orbit nearly coincides with the plane of the earth's orbit; consequently, it is always to be found either upon or very near the ecliptic. It is at double the distance of Saturn from the sun, and is the outermost planet that has hitherto been discovered in our solar system. Its mean daily motion along the ecliptic is but 42·4sec., and its progress in the orbit only 15,546 miles per hour.

The inclination of this planet's axis to the plane of its orbit is not known, neither its diurnal revolution; consequently, we know nothing of the length of its day, or whether it has any change of season. Its magnitude is 90 times that of the earth, but its density is only one-fourth the earth's density; 1lb. on its surface would weigh only 14oz. 14dr. Its quantity of light and heat is only a five-hundredth part of the earth's:—hence, the sun to the inhabitants of this planet can only appear like a star. Herschel at various times discovered 6 satellites belonging to this planet.

WE have here stated the comparative light and heat of each primary planet, on the supposition of the sun being a solid globe of fire, and the light and heat according to the distance: however, as this opinion is now exploded, the real quantity of light and heat will be very different from the above statements; and will depend in a great measure upon the quantity of matter and peculiar electric energies of each. The atmosphere as will be

shewn in the course of this work, is indicative of these energies; and is, perhaps, in proportion to the quantity of matter in each planet; and, as it is found that the light and heat experienced on the earth's surface, are chiefly owing to its atmosphere; so the planet Saturn which has an atmosphere much more extensive than the earth's, may have a degree of light and heat proportionate thereto. And, perhaps, philosophy may ere long be able to demonstrate, that the solar light and heat of all the planets are nearly the same.

10. PLANETARY MOTION.

THE planets are preserved in their orbits by a power called attraction or gravitation. All things upon the earth's surface remain at rest; but yet seem to press against it as if endeavouring to enter the earth: or, if a body be elevated to any height in the air, and then let fall, it will descend perpendicularly, to the plane of the horizon, or along the line of the zenith and nadir: the cause of this tendency to move downwards, as we term it, is what is meant by attraction or gravitation.

Attraction is a property inherent in all matter; and its power is *directly* in proportion to the bulk of the body, or the quantity of matter which it contains; and *inversely* as the square of the distance from that body. Could a pound of lead, therefore be elevated to a distance above the surface of the earth equal to the distance of that surface from the centre, that is, 4000 miles, it would weigh but a quarter of a pound.

As the earth attracts bodies, so the sun attracts the earth and other planets; and they the sun in the direction of their centres. This tendency of planets towards the sun is called the *centripetal* force. To counteract *this*, there is another projectile force acting at right angles with it. Its tendency being to cause the planets to fly off from the orbit, it is, consequently, called the *centrifugal*, force. These two forces are so nicely balanced that the planets' tendency to fly off, or to fall upon the sun is equally divided; and thus they continue to encircle the sun.

The above may be exemplified by twirling round with the hand a stone in a sling. The sling will represent the centripetal force; and the projectile force is what carries the stone round; which exemplifies the centrifugal force as soon as the sling is loosed, when the stone flies off at a tangent to the circle it made round the hand.

The sun and a planet turn round on their common centre of gravity. What is meant by centre of gravity may, in this case, be represented by the steelyard, (see Fig, 15). The point between the weights, on which they are balanced and suspended, is their common centre of gravity. Should they be twirled round upon it, each weight will describe a circle; and the velocity with which they move will be proportionate to that, which each would acquire by falling half the distance between itself and this central point. Now the sun's weight being equal to 337,086 times the earth's weight, their common centre of gravity together with the weight of the moon, which must be added to the earth's weight, is only about 100 miles from the sun's centre. The common centre of gravity of the sun and Jupiter with his satellites, is a little outside the solar surface; and that of the sun and all the planets together, is, at not more than the length of the sun's diameter from its centre. Now if the projectile force were to cease, they would be immediately attracted to each other; and would meet precisely at their common centre of gravity.

The common centre of gravity of the moon and earth is at about 700 miles from the earth's surface. The earth, therefore, in passing round the sun does not describe a regular oval, but this central point describes the line of the orbit. So, likewise, the sun has a kind of orbit: its centre being the common centre of gravity of the solar system.

The elliptical orbits of the planets may seem to form an objection against this theory of attraction; but they, in reality, establish it. For when a planet is in that part of the orbit nearest the sun, the centripetal force is increased, but this tends also to increase the velocity; and therefore the projectile force or tendency to fly off is also proportionately increased. So when the planet is at the part of the orbit, which is at the greatest distance from the sun, its centripetal force is diminished; and for the same reason the velocity is retarded, and its tendency to fly off is less.—Hence, the planets describe equal areas of the planes of their orbits in equal spaces of time.

The difference of the apparent diameter of the sun is what shews him to be at various distances at different seasons; but the variation in the earth's velocity is the most unerring guide. For the planets are found to perform their respective revolutions in spaces of time, whose squares are in proportion to the cubes of their distances from the sun: so that, when the earth

moves quick as in winter, as the square of the time required to traverse a certain space is diminished, so must also be the cube of the distance.

As the primary planets thus gravitate towards the sun, and the secondary towards their primaries, it needs must be that they will attract or gravitate towards each other:—which accordingly is found to be the case. This is observed the most between Jupiter and Saturn. For, the farther the planets are from the sun, and the nearer they are to each other, the more they will interfere. Though Uranus and Saturn are at the greatest distance from the sun; yet, their distance from each other is almost three times that of Jupiter from Saturn: the bulk of Jupiter is also above 16 times that of Uranus. The action of Jupiter when nearest to Saturn is about a 204th part of the action of the sun upon Saturn, which action must considerably disturb Saturn's regular motion. In one revolution, when the two planets were nearly in a line with the sun, Saturn was thus retarded 13 days. Before Uranus was discovered, it was imagined from the confusion in the motion of Jupiter and Saturn, when in conjunction with him, that there must be a planet to cause this confusion. A similar observation led to the discovery of the Asteroids. Comets have also been found to be much disturbed in their motion when in the neighbourhood of the planets, but especially in that of Jupiter.

Besides the want of permanency in the obliquity of the ecliptic, the axis of the earth is found to have a tremulous motion; so that its inclination to the plane of the orbit varies a little every 9 years:—the axis playing backwards and forwards. Both these motions are caused by the action and reaction of the moon and planets upon the earth; and a like irregularity, either less or more, may be observed in the motions of all the primary planets. The attraction of the sun is also found to interfere with the motions of all the satellites. See Chap. III. s. 1

Newton affirms that this partial confusion in the planetary motions will continually increase till the frame of our solar system is destroyed. Hence, he deduces an argument against those who maintain that the world is eternal. While on the other hand, some have dared to call in question the skill of the Almighty, as if his works were imperfect. But the same may be said of animals, whose frames are only temporary. If our solar system be only temporary, it furnishes a proof of the truth of revelation; namely, that the world was created to endure only for an appointed time.

11. HOW THE DISTANCES OF THE SUN AND PLANETS HAVE BEEN DETERMINED.

THE distances of the sun and planets are found by what is called their *parallax*. By parallax is meant the apparent change in the situation of an object, occasioned by a change of place in the observer. Thus: if, while standing at the foot of a tower, we observe the moon or a star to be just over the top of any high object, a chimney for instance; when we have ascended to the top of the tower, the moon or star will be seen considerably above the chimney top. This apparent change of place of the moon or star, with respect to the chimney, is what is meant by parallax; and its extent will be according to the elevation of the tower,—and the distance of the chimney.

Parallax has reference to the place whereat a heavenly body would appear, if we could view it from the earth's centre. A body in the zenith, therefore, has no parallax;—because the eye is in the line between the earth's centre and that body. So likewise when a body is at the horizon, the parallax is the greatest;—the eye being the length of the earth's semidiameter from that line: consequently, the nearer a body is to the horizon, the greater is its parallactic angle;—and it is the less, the nearer that body is to the zenith. As the parallactic angle of a near body is greater than that of a more distant one; the horizontal parallax of the moon will, of course, be greater than that of any of the planets; while the parallax of the fixed stars, on account of their immense distance, is not measurable. As the moon as well as the planets are at various distances at different times, or when they are in different parts of their orbits, the parallactic angle will vary according to that distance.

Now to apply this principle to finding the distances of the various bodies composing our solar system. Two stations on the earth's surface, whose distances from each other are known, must be considered as the height of the tower; the moon or a planet is used as the chimney top;—and by this means the parallax of the sun and moon, and, consequently their distances, have been found.

The most noted method of finding the sun's parallax is by the transit of Venus. For it is obvious that to determine the parallax, the bodies must be in a line with the earth. Let S Fig. 13. be the sun; V the planet Venus; and E the earth. The sun and earth are both supposed to be at rest, while Venus moves

westward in her orbit from A to B with the sum of her own angular velocity, and that of the sun. Let C D be two stations on the earth's surface, in, or nearly in the plane of the orbit of Venus, where two observers are stationed, who see the transit begin when Venus is at the points A and B in her orbit. If the difference of the longitude of the two stations of the observers be accurately known, the time that Venus has taken to move over the arc A B is also known: and therefore from the motion of Venus in her orbit the arc A B is given; or the angle which the line C D subtends at the distance of the sun. Should the line C D be equal to the earth's semidiameter, the angle it subtends at the sun, is therefore, the sun's horizontal parallax which is found to be 8·73 seconds. This angle by a rule in trigonometry bears the same proportion to the semidiameter of the earth, that the sine of a right angle bears to the distance of the earth from the sun; which, in this case, is 93,595,000 miles.

The distance of the earth from the sun being found, the distances of all the other planets are easily determined:—because, as was stated at Section 10:—"The planets are found to perform their respective revolutions in spaces of time, whose squares are in proportion to the cubes of their distances from the sun." So that if we multiply the square of the time of a planet's revolution, by the cube of the earth's distance from the sun, and divide the product by the square of the time of the earth's revolution, the cube root of the quotient will give that planet's distance from the sun.

There are many other methods of finding the parallax; but all are attended with a variety of obstacles, as refraction, and the motion of the earth, all tending to render the process very difficult.

12. THE FIXED STARS.

THE stars which compose our solar system are continually changing their places, hence, they are called planets or wanderers; the other appear always in the same place with respect to each other, and are therefore denominated *fixed stars*. They are at so great a distance from the earth, that when viewed through the largest telescopes, they appear less than when seen by the naked eye; just as the sun appears less through a piece of smoked or stained glass, being divested of his dazzling

brightness. This also accounts for their continued twinkling when we look at them, while the planets shine with a steady light.

The fixed stars are supposed to be suns, in magnitude equal to, if not superior to our sun; with planets and satellites as well as comets revolving round them, and exhibiting all the phenomena of our solar system. For considering their immense distance, if they shone with borrowed light, it would be too faint to reach the earth. Though Herschel was of opinion, that in some of the clusters of small stars which he examined, the stars were too near to each other to admit of planets between them; hence, he conjectured that not all the fixed stars are suns similar to ours, but only the isolated ones.

The distance of the fixed stars, unlike that of the planets, can only be guessed at. We can ascertain that the supposed nearest of them, Sirius or the Dog star, is not less than 19 millions of millions of miles distant. This is inferred from its having little or no *annual* parallax. As the earth is 95 millions of miles from the sun, and makes a circle round him in a year; it is evident, that half a year hence, we shall be 190 millions of miles distant from the place in the universe at which we now are. This changing of place makes the planets appear to be sometimes stationary, and at other times retrograde; but has no effect upon the fixed stars, or at least, so little that it cannot be measured. Were it two seconds it would give the distance 19 millions of millions of miles; but it is not even one; and therefore the Dog star, the nearest of all the fixed stars, is more than twice that distance from us.

For the sake of illustration:—suppose two objects exactly in a line with the observer; the nearest, at the distance of 3 miles, which shall here represent 38 millions of millions of miles, the distance of the Dog star; and the other object at the distance of 5 or 6 miles, representing a star of the second magnitude. Now from the same scale, the diameter of the earth's orbit will only be one inch. Therefore, when the observer has these two objects exactly in a line before him, should he move an inch to either side he will not perceive them to be out of the line: and, not much so if he were to move the diameter of the orbit of Uranus or 19 inches. But should the nearest object represent Uranus, and the other, one of the fixed stars;—then, were he to move the length of the diameter of the earth's orbit; that is, 276 yds. the result would be very different.

It is conjectured that light, though moving at the rate of 12 million miles per minute, would be nearly a year and a quarter in reaching the earth from one of the nearest fixed stars. A cannon-ball, with a velocity of 19 miles per minute, would be 1,128,000 years. As the extent of space is without bounds, and the works of the Almighty, infinite; there may be stars whose light, though travelling with the above velocity, may never reach the earth.

As a body at the distance of the fixed stars appears to have less than two seconds of annual parallax; it follows that the sun, were he viewed from that distance, would appear but as a point;—that is, without any assignable diameter, just as a fixed star appears to us. Therefore we may conclude that the fixed stars are each of them suns, in size and splendor equal to the sun in our system. While, from actual observation, some of them have been conjectured to be a great deal larger.

The stars, which appear larger than the rest, are supposed to be the nearest to us. For the sake of distinction astronomers have divided them into seven classes, according to their apparent magnitude. Calling the largest, stars of the *first* magnitude; the next in size, supposed to be at double the distance, stars of the *second* magnitude; and so forth to the *seventh* class. Those that cannot be discerned by the naked eye are called *telescopic* stars; and these continue, in the same manner, to an unlimited number of classes, or magnitudes. Yet there is no definite line of distinction between any of the classes; so that, they are frequently obliged to call some—stars between the first and second magnitude, or between the second and third, and so forth. In fact, either from their real magnitude, or their various distances, each one of those of the first class differs from all the rest in splendor, as well as the colour of its light.

Some astronomers have calculated that there can be only 13 stars of the first magnitude, allowing the same distance between each as that between the sun and them. This will allow at twice that distance from the sun, space for 4 times the number, or 52 stars of the second magnitude. At thrice that distance 9 times the number or 117 stars of the third magnitude; so that, there will be 637 stars of the seventh magnitude;—which will give an aggregate of 1820 stars, nearly the number that can be seen with the naked eye.

As the stars are not dispersed regularly all over the sky, but are in patches, ancient philosophers called these patches con-

stellations; and assigned each one the name of that animal which they imagined the shape of the constellation most resembled. But as the limbs of these animals could not, in all cases, be so disposed as to take in every star, those not included were called *unformed stars*. Besides this, they gave particular names to several of the largest fixed stars.

However in vain we attempt to discover in the disposition of the stars any resemblance to those animals mentioned in the zodiac, and the others are no better to distinguish; but it should be remembered that in Egypt or Chaldea where the science of astronomy was first cultivated, they have almost cloudless skies with long warm nights. Besides, these astronomers were in all probability shepherds, obliged to watch their flocks by night; consequently they might well enough thus amuse themselves. But as these animal constellations are merely arbitrary signs, without any real foundation in nature, we must refer the reader, who wishes to see more upon this subject, to other books of astronomy.

13. SIR WILLIAM HERSCHEL'S DESCRIPTION OF THE UNIVERSE.

ALTHOUGH the fixed stars do not in general appear to change place with respect to each other; yet, Herschel discovered that about 50 do so in a small degree. Arcturus and some others have a yearly progressive motion of 2 seconds. Some increase in size and brightness for a certain space of time; and then diminish till they disappear, when they again renew their splendor. Several stars mentioned in the ancient catalogues are not now to be found; and some are now seen, which were not seen by the ancients. One appeared in the year 1572 that equalled Venus in brightness. It continued visible 16 months; towards the latter part of which time it diminished gradually, and then finally disappeared. It was situated in the constellation Cassiopea. One appeared in Serpentarius in the year 1604, that surpassed Jupiter in magnitude: it was visible about 1¼ years, and then disappeared; neither of them has been seen since. Thirteen stars are said to have disappeared; and nine new ones have been discovered, some of which are visible to the naked eye.

Some stars appear and disappear periodically, while others have periodical changes of magnitude. Stella Mira, in the

neck of the whale, has a period of about 312 days; its greatest lustre continues for about 15 days;—but it is never quite invisible. The star Algol completes a revolution of variations in 2 days 21 hrs. being by turns a star of the second and fourth magnitude, occupying 7 hours in its wax and wane. The star η Antinoi, continues in its greatest splendor 40 hrs. in its least 30, in its wax 36, and in its wane 66 hours.

Herschel and others have ascertained that the stars in one part of the heavens are apparently, slowly, but gradually approaching nearer to each other; while in the opposite point they are receding:—hence, they conclude that our sun has a progressive motion, taking his attending planets along with him. The point in the heavens towards which we are advancing is λ in the constellation of Hercules. But should we proceed at the rate at which the earth travels in its orbit, and they do not conceive that we move with a greater velocity, it would be 80,000 years before our system could arrive at the place of the nearest fixed star. Consequently, in 1000 years the stars will not appear to have materially changed their places.

Many of the stars which appear single to the naked eye, on the application of the telescope, resolve themselves into two or more. Herschel formed a catalogue of 269 double stars; among which are some treble, double-double, quadruple, double-treble, and multiple. One in the middle of Orion's sword is found to consist of 12 stars very near together. There are even 20 in a nebulous star situated in his head.

Some of these may appear double from their being situated one beyond another nearly in a direct line; and as the solar system in its progressive motion advances beyond that line, these stars will then exhibit a parallactic angle; and will, consequently, recede from each other; while others, for the same reason, approximating to a line with the nearest star, will seem to approach towards it. This will cause something of an apparent motion among all the stars.—However some of the double stars are not of this description. Herchel's observations upon six of them are as follows.

The *first* of these α Geminorum (Castor) consists of two stars, that move round each other on their common centre of gravity. Their orbits appear to be nearly circular; and must, therefore, be at right angles with the line in which we view them. The time in which the small star moves round Castor is nearly 342 yrs. 2 mths. in a retrograde direction.

The *second* is the double star γ Leonis. The smaller retrogrades round the larger, apparently in an elliptical orbit, in 1,200 yrs.

The *third* is the beautiful double star ε Boötes;—which presents the appearance of a planet and its satellite: one of these stars is of a light red colour, and the other of a fine blue. The orbit of the smaller is elliptical; and it performs a revolution in the order of the signs in 1680 yrs.

The *fourth* ζ Herculis, is composed of a greater star of a beautiful bluish-white, and of a lesser of a fine ash colour. The latter revolves round the former in an orbit, whose plane is nearly parallel with the line of observation. In April, 1803, it was nearly hid behind the larger.

The *fifth*, δ Serpentis, consists of a larger and smaller, the latter revolving round the former in 375 yrs. The plane of the orbit is almost at right angles with the line of observation.

The *sixth* or double star γ Virginis, has long been known to astronomers. The stars are nearly equal in size;—the smaller completes a revolution in about 708 yrs.

Besides the above double stars, are nebulous stars, which shew a dim, hazy light:—they are less than those of the sixth magnitude; and are, consequently, not easily distinguishable by the naked eye.

With the assistance of his greatly improved telescopes, Herschel examined every part of the milky-way; and found its brightness to be caused by multitudes of stars at too great a distance to be seen by the naked eye. He ascertained that it is a large shoal or stratum of stars, with some minor branches. These stars it is conjectured are all or most of them suns; similar as to magnitude and other circumstances, to the sun at the centre of our system; so that, were our sun viewed from any other part of the milky-way he would appear only as a small star among the rest.

He further discoverd that all the stars of the universe are in clusters. The extent of a cluster may be guessed at from his considering the shoal of the milky way as one cluster, whose extent, in one direction from the place where we are situated, is not less than 900 times the distance of Sirius, but in the opposite direction, considerably less; so that we are situated at a great distance from its centre.

He supposed our situation in this cluster to be about four stars deep in the main shoal, near where a minor stratum

branches out. At right angles to the most extended direction the cluster is comparatively narrow, so that, when the sky is examined in these directions, that is, out of the sides of the milky-way, the bottom of it appears free from telescopic stars, and to the naked eye assumes a bright blue. Now from the circumstance of the milky way nearly surrounding us, but not entirely so, it is reasonably concluded that we live near the outside of our cluster; perhaps 50 stars from the nearest point, while the naked eye can only reach all round as far as 7; consequently, without the help of glasses, we could have had no conception of the extent of our cluster, much less of the existence of others quite as large.

The telescope with which Sir W. Herschel examined some of these clusters, enabled him to see 6000 times further than can be seen with the naked eye, or as far as stars of the 42,000th magnitude: consequently, he, and others, have discovered not less than 2500 clusters. Yet comparatively speaking, but a small part of the heavens have been examined; for, on account of various circumstances which he enumerates, his large 40 feet telescope could not be effectively used more than 100hrs. in a year; and allowing only a moment for each place, it would require 598 years to sweep the skies. However the heavens are now divided into zones or portions; and each party of astronomers, in different countries, has its own portion assigned; so that this work of searching, or as it is called *gauging* the skies, proceeds apace.

These clusters when viewed with telescopes of smaller power present the appearance of luminous clouds or small patches of the milky way;—hence, they have got the general term of *nebula*. Though these nebulæ, when examined with telescopes of greater power, generally resolve themselves into myriads of small stars; yet, it is not always the case. For in some parts of them are luminous places apparently of æriform matter, that seems to be on the point of assuming a cometary form; each bright spot consisting of a nucleus with a vast luminous envelope. The most remarkable of these is in the great nebula of Orion, (of course in our cluster), and is not farther distant than stars of the seventh or eighth magnitude, and some of it may be as near as stars of the second and third magnitude. This nebula, during the 37yrs. Herschel made observations upon it, underwent great alteration. Similar changes, though in a smaller degree, have been observed in others. (see Chap. XIV. s 1.)

	Diameter in English miles.	Time of performing one revolution round the sun.	Mean Velocity per hour in English miles.	Time of rotatio on the Axis.
☉ SUN	883,246			d. h. 25 10
☿ MERCURY	3130	d. h. m. s. 87 23 15 44	109,442	h. m. s. 24 5 28
♀ VENUS	7700	224 16 49 10	80,062	23 21 7
⊕ EARTH	7914	365 6 9 12	68,092	23 56 4
♂ MARS	4200	686 23 30 39	55,166	24 39 21
⚶ VESTA		1335 4 55 12	44,202	
⚵ JUNO		1590 23 57 0	41,170	
⚳ CERES	162	1681 12 56 0	40,932	
⚴ PALLAS	147	1681 17 1 0	40,930	
♃ JUPITER	91,000	4332 14 19 0	29,866	9 55 50
♄ SATURN	77,680	10758 23 17	22,050	10 16 19
♅ URANUS	34,170	30688 17 6 0	15,546	

It was the opinion of this great man, that, by the power, which he calls the clustering power, the same as the attraction of gravitation, all the stars of a cluster have a tendency to draw nearer to each other; though not to one common centre, but to the formation of smaller clusters. Some clusters that he examined are twice as much condensed as our cluster; but even in it, he says, it is not difficult to point out the commencement of 2 or 300 smaller clusters. Hence, there is ground for conjecture, that now and then it may be necessary for the great Architect, who builds and keeps the whole in repair, to annihilate particular stars that approach too near to others, for the preservation of the whole; just as a well regulated government removes a notorious offender against the general safety: and that, after many ages, they may all rush into a heap. "When the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also and the works that are therein shall be burnt up."

From all this, it is evident, that our sun may be as insignificant a star as the least we can see; and that, to an eye which could grasp the whole in one view, it might, with its worlds, be annihilated without its making a greater chasm in the universe, than would be made in a large forest, were we to deprive any one tree of a single leaf.

As the stars of the universe are formed into clusters; each star having planets revolving round it, and almost each planet its satellites, besides comets in all directions; and as the stars in each cluster are presumed to have an internal motion among themselves;—there is reason to suppose that each cluster may have some kind of a planetary motion round some centre of its own, where the great Ruler of the whole may have a more peculiar mansion. So that as the sun in the centre of our system seems to be stationary, reigning in the full majesty of splendor, and beholding the earth and the other planets with their satellites, as well as the blazing comet encircle its throne; so may the King of systems reign in the midst of this fountain of glory; and behold each cluster containing millions of suns with their worlds encircle His throne. And as we are assured the eternal Creator's works are infinite, the throne of His most exalted glory may not rest here; but this system of clusters may be only secondary to another, as much greater in comparison, as this is greater than our solar system; and thus, the scale of being may rise in infinity:—"Great and marvellous are thy works Lord God Almighty!!!"

CHAP. V.

Gravitation of the Terrestrial Mass.

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1. THE MODIFICATIONS OF ATTRACTION. 2. THE CENTRE OF GRAVITY. 3. THE THREE GRAND DIVISIONS OF THE TERRESTRIAL MASS. 4. VARIATION OF GRAVITY CAUSED BY THE SPHEROIDAL SHAPE OF THE EARTH, AND ITS CENTRIFUGAL FORCE. 5. THEORY OF TIDES. 6. MOTION. 7. MOMENTUM AND IMPARTED MOTION. 8. THE MECHANIC POWERS. 9. SPECIFIC GRAVITY. 10. GRAVITATION OF FLUIDS. 11. THE MOTION OF FLUIDS AS CAUSED BY THE GRAVITATION OF THE ATMOSPHERE.

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1. MODIFICATIONS OF ATTRACTION.

HAVING related what is known respecting that portion of the universe, which is subject to the scrutiny of man; and described the bodies which compose the solar system, as well as their motions; our attention will henceforth be principally confined to the small planet we inhabit. We shall, first, consider it as a mass of matter composed of very heterogeneous materials; all of which are moulded into a spherical shape, by that one great principle called *attraction*. As this universal principle is the great band of nature that holds, not only the planets in their orbits, and moulds them into spheres; but also, causes a drop of rain to assume a spherical shape, at the same time that it gravitates towards the earth—its energy must, therefore, appear under a variety of forms:—all of which have a peculiar designation.

When it is spoken of as holding the planets in their orbits, it is called *planetary* attraction. If of moulding them into spheres, attraction of *aggregation;* which is also extended to all their component materials; and may be examplified as existing in

four states;—*solid*, in stone; *soft*, in jelly; *liquid*, in water; and *gaseous*, in air. But if we refer to that power which prevents the particles of any substance from being easily separated, as a stone, a piece of wood, Indian-rubber, or ice:—it then takes the name of attraction of *cohesion*. When we speak of a body being raised into the air, and then descending by its own weight towards the earth;—the power that causes it to descend is called the attraction of *gravitation*. When two leaden bullets are scraped bright, and firmly pressed together; or when two flat and very smooth surfaces are applied to each other, they will firmly adhere:—and, in this case, the conjoining power is called the attraction of *adhesion*. If a piece of lump-sugar, a bundle of small withs, a piece of cotton in the form of a candle-wick, two panes of glass held nearly together, or a glass tube with a bore no thicker than a hair, be placed with one end in a basin of water; the water will be seen to ascend in them considerably above the surface of that in the basin:—*this* is called *capillary* attraction. There are also the *magnetic* and *electric* attractions; and another that takes place only between the original particles of which any substance is composed:—it is called the attraction of *composition*, or *chemical* attraction.

But however *attraction* may develope its operations, whether in wielding a comet, moulding a drop of rain, bringing it to the earth, binding the particles of a flinty pebble together, lifting it with the adhesion of bird-lime, causing the melted tallow to ascend to the flame along the wick of a candle, the needle to cling to a loadstone, two electrified bodies to approach each other, or the water with which morter is cemented in a wall to become as dry as dust:—still it is the self-same principle, and all these but its various modifications.

2. CENTRE OF GRAVITY.

It was stated Chap. IV. s. 10., that all things are attracted, or, are made to gravitate towards the earth's centre; but in saying so, we do not mean that there is any thing placed thereat, which possesses the power called attraction in a higher degree than any other of the materials composing the earth. Attraction is inherent in all matter; and as much so, in that at the earth's surface as in that at its centre. A drop of any liquid always assumes a spherical shape. The whole mass of the earth we suppose to have been at some time in a fluid state, at

which period it assumed its sphericity; and in process of time became solidified in that shape.

A plumb line, let down by the side of a mountainous precipice, will decline from perpendicularity towards the precipice; or, if a leaden weight and 200 yards of packthread be put into each scale of a balance, so that their weights be equal; and one of the weights be afterwards let down 200 yards into the shaft of a coal-mine, and suspended by the other end of the packthread to its scale,—it will be found diminished in weight: being partly suspended by the attraction of the earth above, as well as pulled downwards by that below. These prove that the earth's centre of gravity is merely the centre of its mass.

It is therefore found that the gravitating power is the greatest at the earth's surface; and on this principle it is calculated, that a pound of lead at half way between the surface and the centre would weigh but half a pound; and at the centre nothing. And the same diminution of the gravitating power takes place above the surface; but as it is not limited in this direction, as it is at the centre of attraction, the diminution varies according to the following scale.

At the earth's centre	0 -	4000 Do. or surface	1 lb.
1000 miles distant ..	¼ lb.	6000 Do.	½ -
2000 Do.	½ -	8000 Do.	¼ -
3000 Do.	¾ -	12000 Do.	$\frac{1}{9}$ -

As attraction is what holds the earth together, so does it act in every body, whether great or small, with a force proportionate to the mass. Hence, every body at the earth's surface will have its centre of gravity balancing all parts upon a line, called the *line of direction*, from that centre to the earth's centre; just as the earth is balanced on a line passing from its centre of gravity to that of the sun, which line is in the plane of the earth's orbit.

If an irregular body, such as a piece of deal board, be loosely suspended by a corner on a pin, from which a plumb-line is depending; the centre of gravity of the board will be in the direction of the line: and if the board be again hung by another corner, the centre of gravity will still be in the direction of the same line; and where these two lines intersect each other is the *central* point. On this point, then, it may be suspended; and whatever way turned it will remain at rest:—its parts being all balanced thereat.

If a person would balance a stick across his finger, the centre of gravity of the stick must be on the very summit of his finger. Should the stick be uniform from end to end, at the exact half length will be its centre of gravity; but should it not, the central point will be nearer the thick end than the small.

The whole weight of any body being, as it were, condensed at the centre of gravity; if this point be duly supported, that is, if the line of direction pass within the base, on which that body stands, the whole will be at rest; but if not, it will fall the nearest way to the ground.

Place a piece of wood A B C D, Fig. 14. on the edge of a table; and from its central point *a* suspend upon a pin, a small weight with a piece of thread, which will represent the line of direction *a b*. Should this line be within the base A B, the piece of wood will stand; but if not, it will fall. Should it be within the base, and we place another piece of wood D C E F on the top, so as to increase the elevation, then, the central point will also be elevated to *c*; and the line of direction *c d* will no longer be within the base.

Several walls and towers are declining so much from perpendicularity, that they threaten every moment to fall; yet, because the line of direction is within their base, they stand firmly, and will ever do so while their materials hold together.

The lower the centre of gravity, the more firmly will a body stand; hence the danger of carriages when the lading is high, or, of stage-coaches with luggage on the top. A cart loaded with lead could hardly be so placed, as to have its line of direction fall outside the wheels; but one loaded with hay, having its centre of gravity at a considerable elevation, requires much care to keep it from being overturned. This shews the folly of people rising in a boat or carriage, that is likely to be upset or overthrown; for by so doing they elevate the central point and greatly increase the danger.

The act of standing is nothing more or less than having the body in such a position, that the line of direction may pass within that space included by the feet. And if a person choose to hold his head to one side, an equal weight of his body must incline towards the other side of the line, otherwise he will immediately fall. The broader the base, and the nearer to its centre is the line of direction, the more firmly does a body rest: hence, we set our feet apart when we wish to stand firmly on our guard. In short, we may be said to be continually turning,

like as many weather-cocks, upon our line of direction; since every movement we make has a reference to it.

Should a person, while standing erect, lift this book from the table, it will increase the gravity on one side of the central line; so that the line will be a little removed from the point where it cut the ground before he lifted the book; or, a corresponding weight of his body is thrown to the opposite side of the line to counterbalance the book and keep the line in its place. Should this not be done, and his feet be close together, the mere weight of this book would throw that person down. It is frequently amusing to see into what various postures men put their bodies while lifting or carrying burdens, or even on the most trivial occasions, as rising from a seat or sitting down; all to keep the central line of their bodies and burdens together, or of their bodies only, within the basis formed by their feet and step. And it is no easy task for a child learning to walk, to learn, at the same time, to keep his line of direction within the basis of his small supporters.

The rope-dancer has a long pole with a heavy knob at each end; the centre of gravity of the whole is marked at the middle of the pole. This mark he keeps nearly over the rope; and, fixing his eye steadily upon something parallel with the rope, in his bounds, when the central line of his body is on one side of the rope, he puts the central mark of his pole to the other side; so that, the central line of direction of himself and pole together may be still at the rope. The general equilibrist proceeds on the same principle, depending on the acuteness of his eye for the perfection of his art. In short, a great many of the operations of life are but struggles with the centre of gravity, and principally depend on counterbalancing the attraction of gravitation.

3. THE THREE GRAND DIVISIONS OF THE TERRESTRIAL MASS.

The earth as a mass may be considered under three great divisions: namely, *solid, fluid,* and *æriform*; or, land, water, and air.

The *solid* part may be called the nucleus, around which the others arrange themselves. On account either of its diurnal motion, or its being under the influence of the attraction of the sun and moon, at the time of the earth's passing from a fluid to

a solid state, it became flatted at the poles; so that, the centre of gravity is not at an equal distance from all parts of its surface.

Nor is its surface whole and uniform. Some time after the nucleus had become solidified, the whole, or at least the external part, seems to have undergone more than one revolution; which have occasioned it to be in a very confused and heterogeneous state, with respect to the disposition of its materials; and have, also, left the surface very uneven. In fact it is all over beset with indentations, cavities, broken precipices and protuberances. Yet, these very little impair the general rotundity; since, they are no more, measuring from the deepest cavity to the highest eminence, than 8 or 10 miles; half of which space is filled with water:—whereas to the centre is 4000 miles. Such unevenness is, therefore, no more to the earth's general rotundity, than the little prominences of the rind are to that of an orange. The whole of this mass is so compressed and fastened together by the attraction of aggregation and cohesion, that it has been demonstrated to weigh five times as much as an equal bulk of water.

The *fluid* part or water extends over about two-thirds of the nucleus. The nearer any part of the earth's surface is to the centre of gravity, the greater is the attraction of gravitation; consequently, it will be greater in the cavities than on the prominences; and water, not being under the power of attraction of cohesion, and its parts rolling loosely over each other, therefore, seeks and gains possession of these cavities. Here then, by the power of aggregation, it would remain, were it not for other causes, as firmly at rest as any of the solid materials. But the attractions of the sun and moon are continually at war with this attraction of aggregation, and partly remove the water from the place nearest the centre; consequently, this motion and the return of the water, together with the motion caused by the wind, keep the ocean in continual agitation. Another disturbing cause is the heat of the sun, which occasions the water to ascend as vapour; and in the form of clouds to spread over the prominences of the nucleus, whereon it descends in rain, and is thence returned by the rivers to the lowest cavities, or places nearest the centre of gravity.

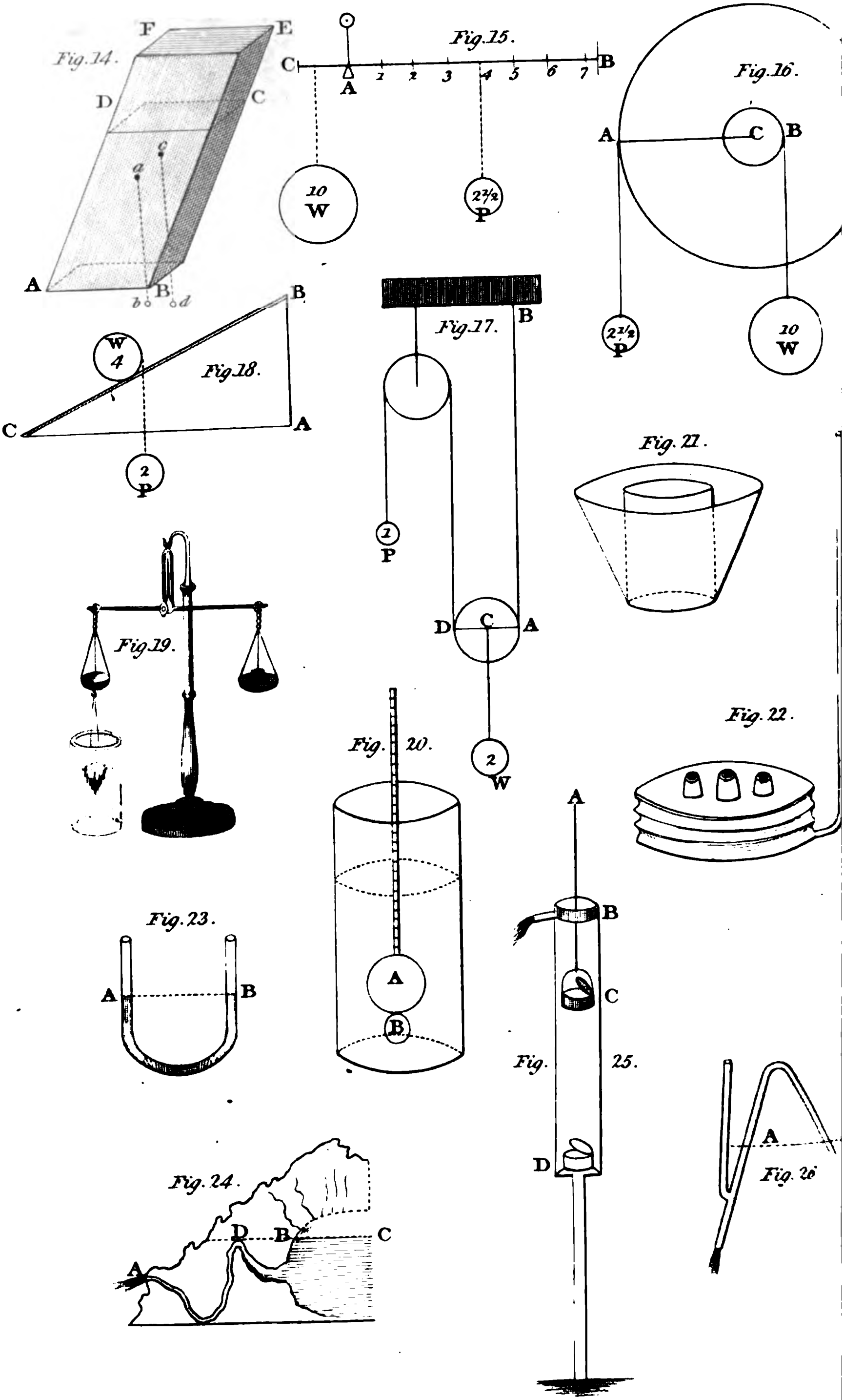
As the water thus embraces the earth, we must consider the surface of the ocean, notwithstanding these little agitations, as every where at an equal distance from the central point of gravity; and, consequently, forming so much of the surface of a

sphere. So likewise inland pools of water are portions or patches of a spherical surface; though each one differs as to the radius of its sphere according to its elevation above the surface of the sea. On this principle, the surface of no portion of water however small can be said to be mathematically flat, or a perfect plane; since, it is a portion of the surface of the circumference of a sphere, whose centre is the centre of the earth. A lake of two miles diameter will have its centre raised 8 inches above its edges.

Hence, it is evident, that was any disturbing cause, as the too near approach of a comet, to remove the earth's centre of gravity from its present place, the ocean would immediately change its bed. For instance: were the central point removed one or two miles nearer to the north pole; not only the lowlands, but all the mountains of the northern hemisphere would be submerged beneath the ocean; while the small islands now in the southern ocean would become the summits of new Alps and Apennines; and the bottoms of the shallow seas would be shortly converted into fertile plains. In this manner have some endeavoured to account for the great Deluge; and on this principle we found our theory of Tides.

The *æriform* division of our planet is the atmosphere that envelopes the whole. It is composed of a mixture of gases, whose proportions and properties will be hereafter described. Considered as a part of the earth, its peculiar distinctive quality is, its expansive force. For, though it gravitates like the other component materials of the earth; yet, such is the repulsive property of those principles to which it owes its existence as air, that, in its being piled around the earth, we can set no definite limits to its extent; though it is found at the height of 45 miles to be so thin as to cause no refraction of the sun's rays. This body of air, gravitating towards the earth's centre, rests upon its surface; and as the particles of which it is composed are inconceivably small, it penetrates every chink or cranny not occupied by water; so that, no place around the earth can be said to be empty, since it must be filled with air.

A pint of atmospheric air taken at the earth's surface, that is on a plain, weighs about 9 grains; or 13 cubic feet weighs about one pound avoirdupois; but if taken at the bottom of a deep pit it weighs *more*; and, if on a high mountain, considerably *less*. This variation arises from its being piled up, so, that the lower part is compressed by what is above; in the same manner, as a



Fenner 50 Pater Noster Row London.

few light bundles of wool or tufts of cotton are compressed when piled one upon another. Taken at a medium, it is ascertained to press upon the earth's surface with a force equal to 15lb. to every square inch. On this principle it is calculated, that the whole of the atmosphere is equal in weight to a solid globe of lead of about 60 miles diameter.

This body of air must be considered as much a component part of the earth, or of our planet as the ground we tread upon; and though it is so very thin at its utmost limits, it moves along with the earth as little incommoded, either by the diurnal or annual motion, as any of the other materials. For we are to consider, that beyond the limits of the atmosphere is mere vacuum. It can, therefore, have no impediment from friction; and, being under the immediate influence of the earth's attraction, it is but little disturbed by the distant attraction of the heavenly bodies.

4. VARIATION OF GRAVITY CAUSED BY THE SPHEROIDAL SHAPE OF THE EARTH AND ITS CENTRIFUGAL FORCE.

THE true figure of the earth is an oblate spheroid; that is, it is a little flatted at the poles like an orange:—the equatorial diameter being 34 miles longer than the axis. Now as the centre of the earth is the point towards which all bodies gravitate; and with respect to bodies *at* or *above* the surface, the nearer the centre the greater the gravitating power; consequently, a body at either of the poles, will weigh more than it would do at the equator. This is ascertained by the vibration of the pendulum. By the attraction of gravitation, pendulums of equal lengths vibrate in equal times, whether the weights and oscillations be great or small. The greater the gravitating power, the faster a body falls to the ground; consequently, the greater the attraction of gravitation of any particular place, the quicker will the pendulum vibrate at that place;—also the shorter the rod of the pendulum, the quicker the motion.

Now it is found that if a pendulum of 230 vibrate in a certain time at the pole; because the gravitation at the equator is less than at the pole, it requires a pendulum thereat of only 229 to vibrate in the same time. Therefore, the equatorial diameter is to the polar as 230 to 229; which, being reduced, makes a difference of about 34 miles.

A pendulum to vibrate seconds in the latitude of London

must be $39\frac{2}{10}$ inches; but at the equator only $39\frac{1}{10}$. One to vibrate only half-seconds, must be only a quarter of that length; and one to vibrate once in two seconds, four times the length of the one vibrating seconds.

As the earth revolves on its axis, the centrifugal force, as caused by the diurnal motion, also diminishes the power of gravitation. This effect is greatest at the equator, decreasing as the degrees of latitude increase, and ceasing entirely before we reach the pole. The earth revolving on its axis in 24hrs., every point on its surface, except its two poles, will describe a circle in that time. Now as the circumference of the earth is 24930 miles, a body at the equator A B Fig. 8, will move through this space in 24hrs.; which is about $17\frac{1}{3}$ miles per minute. In the latitude of London, C D, it will be carried at the rate of about $10\frac{3}{4}$ miles per minute, while at a degree from the poles it will not pass through more than one-third of a mile in that time. Thus: while a body at the equator is hurried forward at the above rapid rate, one near the poles is comparatively at rest. The tendency to fly off must be, therefore, very disproportionate. It is calculated that the weight of bodies is thereby diminished in the proportion of 289 to 288; and that, if the diurnal motion of the earth were 17 times more rapid than it is, the centrifugal force would so far counterbalance the power of gravitation, that bodies at the equator would entirely lose their weight; and if the velocity of the earth's motion were still more accelerated, they would all fly off.

Newton demonstrated that a homogeneous fluid of a mean density with the earth and of the same extent, revolving on its axis in 23hrs. 56min. 4sec. would, in order that all its parts might be in *equilibrio*, assume the figure of an oblate spheroid, having the axis to the equatorial diameter as 288 to 289. It was on this principle that he determined the figure of the earth in opposition to Cassini, and gave occasion to the mission of the French philosophers. (See Chap. II. s. 14). But later philosophers have discovered, that the mass of the earth is not homogeneous, that its centre of gravity is not exactly at the centre of its mass; and that its diameters are as 229 to 230 as above stated.

5. THEORY OF TIDES.

THE attractions of the sun and moon are continually struggling with the earth's attraction of aggregation, and causing, as

it were, a dilation of its central point of gravity into a line; which, consequently, revolves upon the earth's axis and thus occasions the tides.

That the tide on the side of the earth next the moon should be caused by the moon's attraction, we can easily enough conceive; because, we suppose, though perhaps erroneously, that the lunar action merely gathers the waters into a heap. But we cannot so easily conceive how the tide in the other hemisphere is occasioned, since the reaction of the waters will not sufficiently account for its regularity. What is apt to mislead our notions in this respect, is, the want of being reminded, that the moon's attraction does not act upon the waters in the manner of her light, that is, just penetrating a little beneath its surface :—it extends to the most distant particles of the terrestrial mass as if nothing intervened. Thus: the action of the moon is as great at *d*, Fig. 10, as at *e*, (making a small allowance for its being at a greater distance from the moon by all the length of the earth's diameter). Now the earth attracts the moon equally as much as the moon attracts the earth; and, therefore, the moon's effect upon the earth is an increase to the attraction of aggregation in each direction along the line *e d;* which, as to disturbing the waters, will have the same effect as if the earth's central point of gravity was removed to *a*, on one side of the centre of its mass, and to *b* on the other side;—as it were, dilating the centre of gravity along the line M B. Therefore, the waters will subside each way from the points *f* and *g;* and rise towards the points *e* and *d*.

The same may be shewn of the sun's attraction; consequently, at the conjunction and opposition of the moon, the two powers acting in the same line, the dilation of gravitation will extend beyond the points *a* and *b*, and produce the spring tides; but at the quadratures, the sun will dilate the centre of gravity in the direction of *f* and *g;* and as this dilating power is a deduction of that of the moon—the moon's on these occasions will not reach *a* and *b*, and thus we shall have the neap tides.

We are next to suppose the mutual attraction of the sun and moon to form the frustrum of a cone :—the moon being at the smaller end, and the earth at the larger. This disturbing power of the earth's attraction of aggregation will, therefore, converge from the line *f g* towards *e;* but diverge from the same line towards *d;*—so that the water will rise higher towards *e* than towards *d;*—and as *e* has also an increase of elevation from its

being nearer the moon than *d*, by all the length of lhe earth's diameter, consequently as we stated Chap. III. s. 9.—the tide of attraction must be greater than the tide of reaction.

We have another phenomenon of the tides which we believe has never yet been accounted for. The tides do not rise to so great a height directly under the moon, or in the line of direction, as at about one-third of the distance from it; and the time of high water in the line of direction is not less than about an hour and a half after the moon has passed the meridian; two hours after she has passed the meridian at one-third of the distance; at about half the distance, three hours; and at the poles five or six hours. But it is the first instance that we particularly refer to,—for on its explanation the others depend.—As we have supposed a dilation of the earth's centre of gravitation revolving on the earth's axis, though never at right angles to it, except when the moon is on the equator, this disturbance of the gravitating power must move along the earth's surface, at least along the equator, with a velocity of 1000 miles per hour. Now it appears that the current of the tides never moves with a velocity of more than from 5 to 10 miles per hour—the motion of the waters must therefore be left far behind the moon's attraction. But in the latitude of London, the velocity of the moon's attraction is only about 600 miles per hour; if, therefore, the attraction is not so great at London as at the equator, the time the moon's action is continued upon the waters more than counterbalances its deficiency; and, therefore, the waters, having a longer time to rise in, will attain a greater momentum.

But we have not yet taken into consideration the effect that the earth's diurnal rotation has upon the waters. If the solar and lunar attractions affect the earth's centre of gravitation, removing it from the central point of its mass, it must partly suspend the water, and as the earth goes eastward, must cause it to have a westerly motion;—in other words, to be left behind the solid nucleus. But as the velocity of the attraction is much greater than that of the water,—the water is soon left to pursue its easterly course after the nucleus in search of its level. In most places, then, the tides must be a compound of two currents. In the moon's path round the earth these currents will be parallel, but in opposite directions—they will therefore tend to neutralize each other;—consequently, the tides will not rise so high as at a distance from the moon's path, where they will form a considerable angle:—that current following the moon in north

latitude having a south-westerly motion; and the other, being a subsidence from the equatorial regions, a northerly direction. The time of high water will be at the moment of the water's return, or at the conflict of the two currents; and as this will sooner commence in the moon's path than at a distance, so the time of high water will be proportionably earlier.

There is another phenomenon of the tides we have not yet adverted to: viz. the large spring-tides which take place at the equinoxes. As the earth's equatorial diameter is longer than the polar, the velocity of the united attractions of the sun and moon, when at the equator must be greater than when near the tropics; and, therefore, according to our theory these spring-tides should be the least instead of the greatest. But as the earth's centrifugal force diminishes the weight of bodies at the equator, and this loss of weight not being occasioned by a diminution of the earth's gravitation, but a tendency in the bodies to fly off—it will occasion a rise of water towards the tropical regions,—the central line of convergence being along the equator. When the united attractions of the sun and moon are at a distance from the summit of this ridge, as they are when at the tropics, they will counteract the convergency of the waters. But when they are at the equator, they will augment it. Besides, though the attraction at the earth's surface is less at the equator than at the poles, being farther from the central point of gravity; yet, the effect is contrary with respect to the disturbing force of the sun and moon. For, as there is a greater accumulation of matter along the equator, their effect upon the earth will be greater when at the equator than when at the tropics: hence, the spring tides will be the least at the solstices and the greatest at the equinoxes.

However, there is yet, perhaps, a more powerful cause. The spring tides do not attain their maximum till the second or third day after the conjunction or opposition; hence we may conclude that the tides depend a great deal upon the oscillation of the waters. Now when the sun and moon are at the tropics, for instance at the tropic of Cancer, the tide of attraction will encircle the earth at the twenty-third or twenty-fourth degree of north latitude; and the tide of reaction near the same parallels of southern latitude; their oscillation or acquired momentum will consequently be about 47 degrees asunder; and will, therefore, if they do not tend to destroy each other, very little augment each other's force. But when the

two luminaries are at the equator* the oscillations of both tides will act together, or form but one vibration, the momentum will, therefore, be much increased; and this united with the above augmentation, will greatly exceed the diminution caused by the velocity of the luminaries, and thus overcome what at first seemed an objection to our theory.

There might, perhaps, be other objections started, if we were to investigate all the irregularities of the tides as caused by the interposed continents; but we presume they might be as easily overcome; and it would greatly exceed our limits to examine each one separately.

There is a kind of tides called "counter-tides," which are said to be occasioned by "the pressure of black clouds:"—this subject, therefore, belongs to our electro-chemical department, and depends upon what we have denominated uncombined electricity. Now as we have supposed magnetism to depend on the electric energies, and as the approach of the sun and moon towards the magnetic meridian is found to affect the magnetic needle, we have ground for the conjecture, that the tides may be also in some measure affected by electrical causes. This, with some of the causes which we have developed in the above theory, may perhaps constitute what compelled Sir I. Newton to admit, that, as the movements of the seas all over the globe do not correspond with the phases of the moon, "in the periodical return of the tides there must be some other mixed cause hitherto undiscovered."

6. MOTION.

MOTION is the continued and successive change of place of any body; and originally depends upon two causes; namely, *attraction* and *repulsion*. From these two sources of motion *three* primary laws are deducible,—one imaginary and two positive.

The *first*, or imaginary one is built upon the supposition of a

* The want of permanency in the obliquity of the ecliptic is ascribed to the united action of the sun and moon upon the mass of matter in the equatorial regions. This obliquity diminishes at the rate of about half a second every year. (see page 35). Was it to proceed for the space of 164,000 years, the variation of summer and winter would cease; but philosophers affirm that it cannot exceed 2 deg. 42 min., when the obliquity will again increase.

body placed beyond the attraction of the earth or heavenly bodies; though it may be fairly doubted whether there is any where such a place; yet, should there be, it is evident that a body at rest therein, not being disturbed by any external force, would ever continue at rest:—or, if in motion, would ever continue one uniform course of motion. This first of the primary laws may therefore be said to refer to *simple* motion.

The *second* refers to bodies in motion within the influence of the earth's attraction; which, when acting either in a line with the direction of that motion, or at an angle, not greater than a right angle, *accelerates* the motion; but, if it act in a line contrary to the direction, or at any angle less than a right angle, it continually retards the motion. It also refers to a body in motion, and coming in contact with another body either at rest or in motion, producing in it a tendency to move in the direction of its own motion. It likewise relates to bodies at rest upon the earth's surface; being thereto attracted and held so fast by gravitation, that they require a force greater than their own weight to remove them. This unwillingness, as it were, in bodies to move, has been called the *Vis inertiæ* of matter. Being the action of the earth's gravitating power, it is extended along the whole *line of direction*, that is, from the centre of gravity of the body to the earth's centre of gravity. Therefore, should that body be supported upon another body, and the supporting body be suddenly put in motion, it will glide from beneath the supported one; since, it does not affect the earth's gravitating force, which is continually acting upon the supported body. A person standing in a carriage at rest, will fall if the carriage be suddenly put in motion:—his tendency to remain at rest not being altered, while the support of his feet is withdrawn.

Motion cannot be communicated to a body at rest on the earth's surface without a force greater than that of the earth's attraction. Suppose a man weighing 200lbs. to be at rest, that is, pressing against the earth with a force of 200lbs.: it will require a force of more than 200lbs. to put and keep him in motion. Suppose him to be put and kept in motion by a force equal to 400lbs.; then, the earth exerting a force of 200lbs. his progressive force will be 200lbs. Should he be in a carriage, the carriage's suddenly stopping will not affect his progressive force; but, continuing to go forward while the carriage is at rest, he will fall; or, it will require an exertion equal to 200lbs. to prevent his falling. This second law of motion may, there-

fore, be considered as referring to the modifications of *affected* and accelerated motion.

The *third* law of motion relates to reaction, and has its origin in *repulsion*: (see *action* and *reaction*.)

The scientific arrangement of the modifications of motion, as displayed in the *three* grand divisions of the earth, viz. *solids*, *fluids*, and *æriforms*, is as follows.

SOLIDS.—The increase of motion in bodies, as that caused by gravitation simply, is called *accelerated* motion.

Dynamics.—When bodies are free to obey the impulse communicated to them, their motion is always considered with a reference to their central point of gravity;—as if all their force was concentrated at this point;—and the science that treats of them is called dynamics.

Mechanics.—When bodies are not free to obey this impulse; but are fixed to a point as a wheel on its axis; or their motion is modified as in a ball running along the ground;—or they are any how connected with one another;—the science is mechanics.

Statics.—When bodies merely balance each other without motion, the science is statics.

FLUIDS.—*Hydrodynamics* treat of the motion caused by the mere gravitation of fluids. The modifications of this science are,

Hydrostratics, or the mere balancing or weighing of fluids.

Hydraulics, or the laws of fluids in affected motion.

ÆRIFORMS.—*Ærostatics*, the weighing or balancing of air.

Ærostation treats of the buoyancy of air.

Pneumatics.—The laws of air in motion, as principally arising from its elasticity. But in the following pages this technical arrangement is disregarded; and motion is treated of as forming one part of a grand system of the mechanical operations of nature.

Simple motion of attraction of gravitation, is the mere descent of falling bodies, being their tendency to gain a point nearer to the earth's centre of Gravity. It is found that a body falling from a height moves through the space of 16 feet in the *first* second of time. But at the end of that time it will have acquired a velocity that would, if the attraction of the earth upon it were to cease, carry it uniformly through 32 feet in a second; so that, in every second as it descends it gains a velocity of 32. Consequently, it will in descending move through a space of 16+32; or 48 feet in the *second* second; in the *third* second 80 feet; and in the *fourth* 112 feet; and so forth. Or, calling the 16, *one;*

then the spaces moved through in each second may be expressed thus:—1, 3, 5, 7, 9. The whole space moved through in any number of seconds is as the square of the time, thus: if it fall 1 in *one* second, it will fall 4 in *two* seconds, 9 in *three*, and so on.

The laws of motion in ascending bodies are the same. Should a ball be projected perpendicularly, it will be exactly the same time in its ascent from the gun, to the place of its return or highest elevation, that it is in its descent from that point to the gun. Should it be projected with a force that will cause it to ascend 2304 feet; then, it will be 12 seconds in ascending, and 12 in descending:—moving through the space of 368 feet in each second nearest the gun; and only 16 in each one at the greatest elevation.

It is the same if a ball be projected at an angle of 45 degrees; in which case, it will describe a curve. Now should the ball at the highest part of this curve be at the same elevation as the last, namely, 2304 feet, it will be exactly the same length of time or 24 seconds from its quitting the gun to its striking the ground; and, though the spaces passed through vary, the proportions of elevation will be the same.—The reader perhaps may be a little astonished when he is informed, that, should a ball drop from a cannon placed at the top of a tower, at the same moment at which one is fired from it horizontally; or, in such a direction that it shall not ascend higher than the cannon, they will both strike the ground exactly at the same moment; though the one proceed to a distance of two miles, and the other simply fall to the ground at the foot of the tower.

Irregular bodies, that is, such whose centre of gravity is not at an equal distance from all parts of their surface, move in a certain position that has reference to their centre of gravity. For the centre of gravity always endeavours to precede or to get beneath the point of suspension. Now as bodies in motion always meet with some resistance from the air, that resistance may be considered as partly suspending them; and the points of this suspension will be chiefly at the parts of the body which are at the greatest distance from the centre of gravity. In moving through the air, then, this central point always describes the line of the course, whether the motion be direct or in a curve. But as all the parts are not at the same distance from this central point, consequently, the resistance of the air will be the greatest, at the points at the greatest distance from the central

point; and therefore these suspended points will have a rotary motion round the central point.

A chain-shot is two balls fastened together with a strong chain; and being projected from a large gun, the chain is stretched tight on their emission from the muzzle. The centre of gravity of the two balls, should their weight be equal, will be at the middle of the chain; but if one ball be heavier than the other, the central point will be nearer the heavier ball. However, be it where it may, they will not move one after the other, or the two abreast, but will spin round on their common centre of gravity; so that, only this central point will move in a line, and the two balls will form concentric circles round it all the way as they proceed. Every body we throw into the atmosphere, or drop from an eminence would do the same, were it not for the resistance of the air. Arrows have a tendency to do so; to counteract which, they are trimmed with feathers; that they may, as it were, plough the air, and gain steadiness at the expence of velocity.

In all the above statements the resistance of the air will be considerable. It is calculated that the resistance of the air to a metallic ball of two pounds weight, moving 2000 feet per second, is equivalent to 60 times the ball's weight; and that bodies falling through the air with a velocity of 22 feet per second, meet with a resistance equal to above one pound weight for every square foot of surface opposed to the medium. This resistance is increased according to the square of the velocity; so that a double velocity will have a fourfold resistance; or, half the velocity only one fourth of a pound.

The length of pendulums must be calculated from the point of suspension to the point of oscillation. In such pendulums as have a small wire rod with a heavy head, the point of oscillation is near the middle of the head. But should a rod of thick wire, uniform throughout, and without a head, be used, the point of oscillation or that to which the length of the pendulum must be measured, is at *two-thirds* from the point of suspension.

The vibration of pendulums is as the square root of their lengths; that is, if a pendulum one foot in length, vibrate in a certain time; one four times as long will vibrate in *twice* that time; one nine times as long in *thrice* the time: being regulated by the same law as falling bodies. The force acquired in falling carries it to nearly the same height on the opposite side; though it has to overcome the friction, the resistance of the air, and

the action of gravitation upon it while it is ascending. In clocks a weight is added to counterbalance these, and to give an impulse to the works.

The centre of percussion in weapons is the same as the point of oscillation. If a person take a stick by one end and strike, hitting the object at or near the other end, the blow will be feeble, and the stick will shake his hand. But should he hit the object at the point of oscillation, the blow will be powerful with no jerk at the hand. Should the stick be uniform throughout, this point will be at two-thirds the length from the hand; should it be a bludgeon, it will be considerably nearer the thick end; but in hammers, whose weight is principally in the head, the point of percussion is there also, yet not at the centre; and every workman always holds his hammer, and gives the blow with reference to this point; or, if he do not, every stroke will reprove his want of skill. The truth of this position is demonstrated by the appearance of much used hammers: that part of the face at the greatest distance from the handle being the most worn, the point of percussion lying on that side of the centre of the head. As to saving the hand, the effect will be the same should the stick be grasped at what was in the above case the point of oscillation, and the object hit at the point of suspension; but the blow will be less powerful.

7. MOMENTUM AND IMPARTED MOTION.

MOMENTUM is the force with which a body moves, and is in proportion to its velocity multiplied by its weight. We may place, without any risk, a piece of metal of considerable weight upon a china plate, and it will not break it: but should we elevate the metal, in a very small degree, and let it drop upon the plate, it will break the plate in pieces.

If a body weighing 10 lbs. move at the rate of one foot in a second, it will strike an opposing body with a force of only 10 lbs. But should it move at the rate of 16 feet per second, it will strike the opposing body with a force of 160 lbs.; or, if it move with the swiftness of a cannon-ball, which has generally about the same velocity as sound, or 1140 feet per second, it will have a momentum of 1140 lbs.

Hence, the cannon-ball of modern times does much more mischief than the battering-ram of the ancients. Suppose a battering-ram to weigh 20,000 lbs. and to move at the rate of

two feet per second; then, its force will be 40,000lbs. But a cannon-ball of only 24lbs., moving with a velocity of 2000 feet per second, will strike a wall with a force of 48,000lbs., one-fifth more than the battering-ram's force.

On this principle depends, in some measure, the art of gunnery; for, the force of descending shells, and of balls moving point blank may be thus calculated. Also several mechanical operations, such as driving piles, may be regulated, by calculating the momentum of the descending hammers. If a hammer weighing 200lbs. descend 64 feet; it will do it in two seconds; and will then have a velocity of 32×2, or 64 feet per second; so that its stroke will be 12,800lbs.

General Rule.—Divide the number of feet elevation by 16, (the space fallen through in one second), and the square root of the quotient will be the time in seconds of the descent; which being multiplied by the velocity acquired in each second, and then again by the weight of the hammer, will give the momentum. *Example.* A hammer weighing one hundred weight is raised 8 feet; what is the value of its stroke? $8 \div 16 = \cdot 5$. $\sqrt{\cdot 5}^2 = \cdot 70$. $\cdot 70 \times 32 = 22\cdot 4$. $22\cdot 4 \times 112 = 2508\cdot 8$ the momentum.

From this it appears that the momentum is as the square root of the height: and, therefore, if a body falling a certain height, have a momentum of 1: then, one falling four times as high will have 2, one nine times as high 3, and so forth.

The change of motion is always proportionate to the moving force by which it is produced; and it is made in the line of direction in which that force is impressed. If a certain stroke will make a ball proceed to a certain distance, then, a stroke of double force will make it proceed to nearly double that distance, (allowance being made for the resistance of the air, which is greater in proportion to the square of the velocity). A body struck in the direction of the centre moves in a line; but if the stroke be not central, it will have a curvilineal motion, the nearer the centre the larger the curve; and as it proceeds it will revolve on its axis: the axis being at right angles to the direction of the stroke.—The planets have been sometimes supposed to have had such a motion imparted to them at the time of their being launched:—hence, their *diurnal* and *annual* motions. But what we consider as a better explanation of these phenomena, will be given in the course of this work.

If two bodies strike another at the same time, but not in the same direction, it will obey neither of them; but will have a

motion whose direction is compounded of both. As when the wind blows at right angles across a river, a boat will neither obey the current nor sail with the wind; but, if the impulses are equal, will steer a course half way between. Should the wind and current proceed each at the rate of 6 miles per hour, the boat will then move at the rate of nearly 8½ miles per hour. *Rule:* add the square of the wind's velocity, to the square of the current's; and the square root of the sum, will be the boat's velocity.

Action and *Reaction* are always equal and contrary; that is, the action of two bodies on each other is always equal, but in contrary directions. If, while standing in one boat, a person draw another of equal weight towards him, they will both move, and meet at a point exactly half way between the two. If the force with which a bird strikes the air beneath it, be equal to the weight of its body; then, it will keep at the same elevation: but should the force of the stroke downwards, be greater than the gravity of the bird's body, it will ascend; or if less, it will descend.

If a blacksmith strike his anvil with a hammer, action and reaction being equal, the anvil strikes the hammer as forcibly as the hammer strikes the anvil. Should the weight of the anvil be greater than the momentum of the hammer, then, the anvil, by what is called the *vis inertiæ* of matter, will not be moved. Hence, people have sometimes been astonished at a man lying on his back, with an anvil placed on his breast, while another strikes it with a heavy sledge hammer. Suppose the hammer weigh 10 lbs.; and move with a velocity of 16 feet per second; then, it will strike the anvil with a force of 160 lbs. but the anvil, perhaps, weighs 200 lbs.; consequently it will not be moved, and the man will receive no harm. But were a body of only a few pounds weight placed there instead of the anvil, the blow would kill him.

But though *action* and *reaction* are reciprocal; yet, this depends in a great measure upon the elasticity of the component materials of the acting bodies. An elastic body is that which yields to any impulse or pressure; and is thereby made to change its figure; but, it endeavours by its inherent repulsive property to resume the same form. Repulsion is, therefore, stiled the antagonist of attraction. Its nature, as will hereafter be shewn, depends on the electro-chemical properties of matter, whose particles attract each other, till they approach to within

a certain distance; but when compressed nearer than this prescribed limit, repel with the same force with which they are compressed.

The most elastic substances are the *æriforms*:—such as atmospheric air, steam, and the æriform state which gunpowder assumes, when in the act of explosion. In *solid* substances it is the most exemplified in springs; whether made of tempered steel or tough wood. But all solids as well as *fluids*, possess it to a certain degree.

8. THE MECHANIC POWERS.

COMPOUND motion of attraction, is, when the simple motion is made to counteract itself. All motion of this kind may be considered as depending upon the lever. The six mechanic powers, namely, the *lever*, the *wheel and axis*, *pully*, *inclined plane*, *wedge*, and *screw*, are still reducible to the same principle, of counterbalancing or dilating the gravitating power.

The *lever*.—The poker with which we stir the fire is an exemplification of the lever. But the reader will readily perceive, that the motion of gravitation cannot be made to counteract itself without a point of suspension, whereon to make the counterbalance, or change the direction of the power. This point is called the *fulcrum* or prop: see A Fig. 15. In the act of stirring the fire, a bar of the grate becomes the fulcrum, on which the poker or lever rests; and the counterbalancing weight is the hand. The power, that is, the hand is therefore at the long end of the lever:—*this*, is called a lever of the *first* order. But sometimes the fulcrum is at one end of the lever, the acting power at the other, and the weight to be raised, between them: *this*, is a lever of the *second* order. And sometimes the fulcrum is at one end, the weight to be raised at the other, and the acting power somewhere between; *which*, constitutes a lever of the *third* order.

The lever, therefore, may be considered as the instrument, by which gravitation is made to counteract itself, by dividing or dilating its force. If we would balance equal weights; then, the fulcrum must be at an equal distance from each end. If we would make one pound balance two, the long arm must be just *twice* the length of the short one. If one pound is to balance three, the long arm must have *three* lengths;—if four, then *four* lengths.

The steel-yard is on the above principle, see Fig. 15. The gradations 1, 2, 3, 4, on the *longer* arm A B are found by dividing the greater weight by the lesser, and multiplying the quotient by the shorter arm A C: or by multiplying the greater weight and shorter arm, and dividing the product by the lesser weight. The product of the lesser weight and longer arm, divided by the greater weight, will give the length of the *shorter* arm. The weight W of any mass that can be balanced by the assistance of a lever with a small weight P, may be found by multiplying the smaller weight and longer arm, and dividing the product by the length of the shorter arm. Or, having two unequal weights, one at each end of a beam of a certain length, to find the centre of gravity or length of each arm. *Rule:*—as, the united weights are to the whole length of the lever, so is the lesser weight to the *shorter* arm; or, the greater weight to the *longer* arm.

Whatever distance each weight moves, it describes the arc of a circle, whose radius is the arm; and, as the circumferences of circles are in proportion to their radii or diameters; if a man would by the help of a lever multiply the gravitating power of his own body four times, he must move over four times the space that the object moves over; so that, what he gains in power he loses in time.

From the above statements it is obvious that the power of the lever is unlimited; for with a firm prop and a lever of sufficient length the greatest weight may be balanced by the smallest. Hence, the famous saying of Archimedes: "Give me a place whereon to fix my prop, and a lever of sufficient length, and with it I will lift the world."

The *wheel* and *axis*. This power is used in all kinds of machinery; as, the crane for raising heavy bodies, the capstan in ships, the horsewheel in the thrashing machine, the water-wheel in mills, the stepping-wheel of the treadmill, and many other machines; in all which the motive power is applied to the outside of a large wheel, as at A, Fig. 16. The length of the longer arm of the lever is the distance from the circumference of the wheel A, or the point where the power is applied, to the centre of the axis C. The shorter arm is the semidiameter of the axis or C B. If a rope be coiling round the axis, then, the thickness of the rope must be added to the shorter arm. On most occasions a wheel is fixed to the axis; and then the semidiameter of this wheel is the short arm. Suppose the semidi-

ameter of the larger wheel to be 4, and that of the smaller 1, then the power will be as 4 to one, or 2½ lbs at P, will balance 10 at W:—but the point A will move, when the wheels are in motion, over four times as much space as the point B.

The large wheel of the treadmill is a long cylindrical wheel of about 8 feet diameter, with cogs reaching the whole length of the cylinder. The axis of the wheel being placed horizontally, the cogs serve as steps for the culprits. Suppose the point where the power is applied be 4 feet from the centre, and the wheel on the axis be one foot diameter, then, the power gained will be 8.

A horse confined to the usual narrow tread of a machine, will pull, for eight hours a day, with a force equal to 200 lbs. Suppose the average weight of each man's body be 140 lbs. all of which is on the step of a treadmill; therefore, the power of a man to that of a horse is as 140 to 200, or as 7 to 10. So that 10 men in a treadmill will do, (though for a shorter time), as much as 7 horses in the confined walk of a thrashing-machine. But a man pushing round a beam horizontally, or turning a windlass, cannot exert a force equal to 70 lbs—longer than he can exert his strength on the treadmill:—hence, it is evident that the most advantageous way of applying a man's power is that of the simple gravitation of his body; his muscular strength being employed to counteract the force of gravitation, in the raising of his body.—The principle of the treadmill, as to labour, is exactly that of ascending a flight of steps in a stair-case, so that the exertion increases according to the velocity of the wheel.

The *pulley*.—A pulley is a small wheel turning upon a very small axis, with a groove on the edge, and a small rope passing over it. Pulleys are of two kinds, *fixed* and *moveable*. No power is gained by a single fixed pulley; but it is very useful in changing the direction of the draught, as in raising materials to the top of a building; it likewise permits several persons to apply their strength to one article.

But a moveable pulley becomes a mechanical power, as represented in Fig. 17. In reducing this to the lever, A is considered as the prop, C the centre, and D A the long arm. Now as D A is double C A, with a cord fixed at B, and passing under the first pulley, and over the second, a person at the small weight P, by the exertion of a force equal to 100 lbs. would raise 200 lbs. at the larger weight W. But he will have

double the length of rope to coil, that he would have if the weight was raised with only one pulley.

Pulleys are variously arranged; one block often containing 3 or 4: the upper block being fixed, and the lower moveable. The power gained is always equal to double the number of pulleys in the lower block. Should the lower block contain three pulleys, then, a man will raise *six* times as much at once, as he could with one fixed pulley: but he will be six times as long in doing it, so that, the power is in fact equal. But should he have an article whose weight equals six times his power, and which cannot be divided; then, we see the utility of the mechanical power of the pulley.

The *inclined plane*.—The principle of the inclined plane may, in some respects, be more directly reduced to simple gravitation, than explained on the principle of the lever. It consists of a strong piece of timber laid in a sloping direction; and its power is equal to its length divided by the perpendicular height of its elevated end. It is chiefly used for raising great weights to moderate heights, as a large stone or a hogshead of sugar into a waggon.—Let C B, the length of the inclined plane, Fig. 18, be 32 feet, and the elevation of its end, A B 16 feet; then its power is as two to one. That is, a hogshead W, weighing 4cwt. may be balanced upon it by a force, P, equal to only 2cwt.—A little more than this, will make it ascend; and a little less, will permit it to descend. The hogshead would descend along the perpendicular B A, 16 feet, in one second; but it would be two seconds in descending along the inclined plane B C; so that, the time lost is still equal to the power gained.

The *wedge*.—This may be considered as two inclined planes, having their horizontal sides, C A, Fig. 18, conjoined. Its power is as the length of one sloping side C B to the thickness of the back; or twice A B; but its chief advantage arises from its enabling us to apply the power of momentum. The wedge is generally used in splitting wood or stone; but the driving of nails and piles and even of the sewing-needle is reducible to the same principle. Where the rent precedes the edge of the wedge, the sloping side must be calculated from the angular point of the rent, to the back of the wedge.

The *screw* is the last of the mechanic powers, and is reducible to the inclined plane: its power is according to the closeness of the threads. Suppose there are four threads to an inch; then, to raise a weight the height of one thread, that is, a quarter of

an inch, the screw will have to be turned once round. And suppose its diameter to be an inch, then the space moved over will be three inches, the circumference of the screw; and the power gained will be 12. But the principal power obtained from the screw, is, by applying a lever to turn it. Should we apply a lever of 20 inches the longer arm to the above screw, the power gained thereby would be as 20 to ½, or 40 to 1. Which, multiplied by that gained by the screw itself, will make a power of 480.

All machinery depends on a skilful application of the above powers. But such is the friction of the different parts, that one fourth, and, in many cases, one third must be allowed. So that, when a man with a system of pulleys calculates that he can raise 12 times his own weight, he will find that he can raise but 8 or 9 times that.

All animal motion, whether it be that of a man lifting his arm, a race-horse on the course, or a bird in the air, is still on the principle of the lever.—But they act with disadvantage, the motive power being at the short end. The contraction of the muscle pulls the tendon, which is fixed to the bone. The bone is the lever, and the fulcrum is at the joint. The place therefore to which the sinew is fixed, will be nearer to the joint or fulcrum, then the other end of the bone, where the weight to be removed is placed, or where the required motion is to be produced.

In the locomotion of animals, the earth pressed by the foot, or the air struck by the wing, becomes the fulcrum; and the progressive motion is the result of a number of levers worked in the body:—some lifting it up, or overcoming the gravitating power, and others pushing it forward, though this last motion is chiefly given by the simple motion of attraction. For were we carefully to observe, we should find that a man's *line* of *direction* always precedes his steps; and he might as well try to fly as to walk with this line behind his steps. Hence, whatever animal we examine, we shall always find that a considerable portion of its body, as its head and neck, is at the front of the fore-legs, with nothing to counterbalance it in the rear of its hind-legs; and that such animals as have not the principal bulk of their bodies balanced over their fore-legs, have the hind-legs very disproportionately long. It has been observed that a man, by the peculiar construction of his body, can ascend a hill proportionately, with more ease than a quadruped.

9. SPECIFIC GRAVITY.

By Specific Gravity is meant the various weights of equal bulks of different substances, or the various forces with which different bodies of the same size gravitate. Thus: a cubic foot of lead is equal in weight to 45 cubic feet of cork; or a piece of lead will gravitate with 45 times as much force as an equal bulk of cork. Lead has, therefore, a greater specific gravity than cork; or, in common language, it is heavier.

The reader must here distinguish between *force* and velocity: the latter belongs entirely to *absolute* gravity, in which all bodies are equal, whatever their bulk and materials. A feather is equal in absolute gravity to a cubic foot of lead; that is, it is as much, and as swiftly attracted towards the earth. But we are accustomed to see bodies gravitate in air; and are therefore, not sensible of this universal effect of gravitation. Should a feather and a leaden weight be dropped at the same moment from an eminence, the feather would be buoyed up by the air, while the lead would meet with little resistance. But, were we to exhaust a large vessel of the air, and let those two bodies gravitate in *vacuo*, the feather would touch the bottom axactly at the same moment with the lead. Hence, the *absolute* gravity is equal; but, their *specific* gravity or weight is very unequal.

All specific gravity must, therefore, be founded upon comparison; and water has been fixed upon as the standard. The specific gravity of water being known, that of any other substance may be easily ascertained. If any body, that will sink in water, be first weighed in air, and then in water, it will be found to lose weight in the water:—the weight in the air, divided by the weight lost in the water, is the specific gravity. Thus: a guinea weighs in air 129 grains; but, if we suspend it by a horse-hair from one of the scales of the Hydrostatic Balance, Fig. 19. and immerge it in water, it will be found to lose 7¼ grains. Divide 129 by 7¼, and it will give 17·793 as the specific gravity of the guinea: the specific gravity of water being always considered as 1·000.

The principle on which the above calculation is founded, is as follows:—the body always displaces a quantity of water of exactly the same bulk with itself; and the weight lost in the water is the weight of the water. Therefore, if a body weigh *so much*,

and an equal bulk of water *so much*, the one being divided by the other, the quotient will shew how many times the one is heavier than the other. In the above experiment, the guinea is found to be more than 17¾ times heavier than water.

Specific gravity is of great utility in ascertaining the alloy of the precious metals. The specific gravity of pure gold is known to be 19·640; therefore, the above guinea having a less specific gravity, is alloyed with a metal whose specific gravity is considerably less than that of gold.

Gold and Silversmiths are allowed a certain quantity of alloy in the fabrication of *plate;* and the mixture is called the *standard.* When an article is manufactured, it is taken to the Goldsmiths' Hall, where its specific gravity is ascertained. Should it be below the standard, that is, should there be more alloy than the law allows, it is broken to pieces, be the workmanship ever so exquisite. But if the specific gravity be according to the standard, it is then stamped with the lion and king's head, and returned to the manufacturer. Plate offered to sale without these marks, is under the same law as other contraband goods:—the penalty being £50.

The specific gravity of any substance, consisting of small fragments, may be ascertained by means of a small bucket, for which due allowance must be made. But the easiest method is to weigh them in air; and, having a vessel filled with water to the edge, then, drop the fragments gently in, and a quantity of water equal in bulk to themselves will escape over the vessel's edge. Then, add the weight of the fragments in the air and the weight of the vessel of water together; and from their united weights, substract the weight of the vessel with the fragments in it, and the remainder will be the weight of the water escaped; by which, as above directed, divide the weight of the fragments in the air.

Plunging bodies in water is no less useful for finding the measure of their bulk; since, they always displace a quantity of water equal to it. By this means, therefore, the cubic magnitude or solid contents of the most irregular body, even that of a "Hawthorn Bush," as the schoolboy's phrase is, may be easily ascertained.

In bodies lighter than water, the specific gravity is found by weighing them in air, and then adding weights to them till they just sink in water :—the additional weight, and the weight in air

added together, is the weight of an equal bulk of water; and this, divided by the weight in air, shews how much, or how many times lighter that body is than water.

From many experiments it is found that a living person, on account of the air in his lungs, is one-ninth lighter than water. Therefore were he to lie on his back in water, and keep his hands and his feet under the surface, his face would remain above water and he would not drown. Four pounds of cork are found sufficient to keep a middle sized man's head wholly above water.

The specific gravity of fluids may be ascertained in various manners. A cubic foot of rain water, which next to distilled water is the purest, weighs 1000 ounces. If a fluid, therefore, be balanced by weights with a corresponding bulk of this water; the weights, if added to the fluid will shew how much it is lighter than water; or if added to the water, how much heavier. But a much more elegant method is practised with an instrument called the Hydrometer: see fig 20. A body that will just sink in water level with the surface, is considered of the same specific gravity with the water. One, therefore, of less specific gravity will swim with some of its bulk above the surface. Should such a body as the latter be placed in a fluid of greater specific gravity than water, more of its bulk will be above the surface; but if the fluid is of less specific gravity than water, less of its bulk will be above the surface. In each case the body will displace so much of the fluid as is equal in weight with itself:—on this principle is the hydrometer constructed.

The hydrometer consists of a glass bubble or a hollow metallic ball A; to which is affixed a small metallic knob B, with a stem at the opposite side. The centre of gravity being nearly at B, the stem is always perpendicular to the surface of the liquor when the instrument is placed in it. The depth to which this bulb sinks the stem in distilled water is marked 1·000; and the stem is graduated above and below. Spirits of wine, or alcohol has the least specific gravity of all fluids, (ether excepted); when very highly rectified, it is considerably below ·800. But what is called *proof spirit* contains a large quantity of water, and has a specific gravity of ·930. However, between ·800 and 1·000 is generally the strength of all spirits. The instrument, therefore, according to the weight or specific gravity of the materials of the stem, will sink deeper in the alcohol than in the water; and with spirit previously rectified the gradations on

the scale may be numbered. The deeper the hydrometer sinks in spirit the stronger the spirit is; but in worts, or brine in salt works, it is the contrary; for, the basis of these being water, the ingredients which give them strength only increase the specific gravity of the water,—not its bulk; and, therefore, its buoyancy is increased: consequently, more of the stem will remain above the surface.

There are several variations in the construction of the above instrument, but all are on the same principle. It is chiefly used by officers in the Excise, spirit-merchants, distillers and rectifiers; for, with it they can immediately ascertain the strength of the wash in a distillery; or, in what proportion the pure spirit and water exist in any liquor; and if above proof can at once determine what quantity of water may be added to reduce it to that standard, or any required strength.

Sea-water, on account of the salts that it contains, is generally about one-fortieth heavier than river water; and, of course, more buoyant. A ship, therefore, loaded till it sinks as deep as it will sail in salt water, would go down when it came into fresh water:—on the contrary, what may appear a heavy load in fresh water, will prove an indifferent one in salt water.

10. GRAVITATION OF FLUIDS.

FLUIDS are subject to the general law of gravitation the same as solids; but on account of their not being restrained by the attraction of cohesion, each particle gravitates on its own central line of direction; whereas the particles of solids gravitate on that of the whole mass. Thus; in a vessel, Fig. 21, that has a narrow bottom and wide top, filled with water, the pressure is on all parts of its sloping sides in proportion to the perpendicular height of the water; so that, the bottom has no more pressure than if the top and it were of the same diameter. But with respect to the vessel itself pressing the earth, it is to be considered as a solid; and should not the central line of the whole be within the area of the bottom, it will, of course, fall and spill the water.

The downward pressure of water is at its perpendicular height. The bottom of a canal or reservoir may be sufficiently compact to retain a depth of water equal to 16 inches, without a drop oozing through. But were the depth increased to 16 yds.

it would require a bottom of 36 times the firmness; otherwise, the water would pierce through the materials, and cause the whole to give way.

The lateral pressure of water is as half the height; that is, "If the side and bottom of a vessel be equal, then, the pressure on the bottom is twice as great as on the side." But the pressure against any particular part of the side, is, as the greatest perpendicular height of the water without any regard to the extent of its upper surface. The knowledge of this law is of great importance in the construction of flood-dikes and sluices; for, "it is obvious that the thickness of the wall at the bottom must be greater than at the top, as it has a much greater pressure to withstand. If the wall at the bottom be two-fifths of the height of the water, it will just balance the pressure of the water. A secure wall would require to be thicker."

The spouting of water is as the square root of the perpendicular height. If holes be made at different distances from the top of an upright column of water, it will be spouted from each hole with a velocity or in quantity proportionate to the square root of the distance from the top. If this distance be 4 feet, the proportionate quantity will be 2:—say, two pints per minute. If 16 feet, 4 pints per minute: and if 192 yds. then 24 pints will be spouted in the same space of time. The miller is well acquainted with the principles of this law; and loves to have what he calls "a good breast," that is, his reservoir so full, that the surface of the water may be considerably above the aperture where it spouts upon the wheel.

The spaces described by the descending surface of the water in equal portions of time, are as the odd numbers 1, 3, 5, 7, 9, &c. taken backwards. On this principle were water clocks formerly constructed. Suppose an upright column of water to be 12 hrs. in emptying: then, this column must be divided into 144 parts; and there will be 23 times as much water spouted the first hour as the last. The proportions spouted in each hour will be these, 23, 21, 19, 17, 15, 13, 11, 9, 7, 5, 3, 1. But the numbers counting from the top downwards, marking the hours, I, II, III, IV, &c. will be thus, 23, I; 44, II; 63, III; 80, IV; 95, V; 101, VI; 119, VII; 128, VIII; 135, IX; 140, X; 143, XI; 144, XII.

Water has also an upward pressure, which depends likewise on the simple law of gravitation; or, as we express it in common language, "finding its own level." It is exemplified by

what is called the hydrostatic bellows. This apparatus consists of two boards fastened together in the manner of a common bellows; but there is no aperture except by a long pipe fixed perpendicularly, as in Fig. 22. Now, how small soever the bore of this pipe may be, providing water will flow freely along it, and it be perfectly perpendicular, should we fill it with water and keep filling it; the water will raise the upper board with any weight upon it proportionate to the height of the pipe. A quibble is founded on this law, called the hydrostatic paradox; wherein it is said, that "a quantity of water however small may be made to counterbalance another quantity however large." Now, an upright column of water 28 inches high, presses with a force of one pound upon every square inch; and this is the same whatever be the diameter of the tube. Therefore, should we, having a bellows containing a little water, and with a pipe 28 inches high, place such a weight on the upper board as shall contain as many pounds as the upper board contains square inches, the pipe will stand full of water. If the weight be less than a pound to each square inch, the water will fall so low in the tube, that its upright column shall press an equal weight on a square inch to that which each inch of the upper board sustains. But should there be more than a pound on each inch, then, the water will spout out at the top of the tube. The power of this bellows is therefore unlimited; and depends both upon the height of the tube and size of the board. Though the bore of the pipe may be such, that it shall not contain one ounce of water; yet, if the upper board be a square whose side is 48 inches, this small quantity shall lift a ton weight placed upon the board; for there will be less than a pound on each square inch. Should we double the length of the pipe, then, the pressure on each square inch will be two pounds, and with the above board and continually filling the pipe, the water will raise a weight of two tons.

Should a person stand upon the upper board, and blow into the pipe, he may raise himself equally as with the water; so that, in this sense, it may not improperly be said, that a man with his own breath, may blow himself up into the air.

The *hydrostatic press* is a slight variation in the construction of the above apparatus. It is so contrived, that the water by the assistance of a powerful lever, a piston and valves is pressed down in the smaller pipe. The small pipe is bent and fixed into the lower end of a wide cylinder. Upon the water in this

cylinder, is a piston fitting the cylinder so accurately that no water can escape.—The force with which this piston may be raised, will be in the proportion, that the square of the diameter of the cylinder, bears to that of the small pipe, multiplied by the power of the lever. Suppose the diameter of the cylinder to be 40in. and that of the small pipe one inch, the power gained will be 1600. And suppose a power of 200lbs exerted at the lever: then the power of the piston will be 320,000lbs. Now, as the disproportion between the diameter of the cylinder, and that of the small pipe may be of any extent; and almost any force may be obtained by the lever;—it is evident, that the power of the hydrostatic press is unlimited;—hence, a man with the greatest ease may tear up trees of the most sturdy growth.

It is obvious from the above laws of water, that if we take a bent tube, Fig. 23, and pour water in at one end, it will rise in the other leg till the surface of each is at the same level, A B. On this principle many fountains both natural and artificial depend. The artificial are merely water flowing in at the higher leg of a bent tube, and spouting from a smaller orifice in the lower leg, with a velocity proportionate to the elevation of the surface of the water standing in the longer leg above the spouting orifice. The extent of such a tube is unlimited; and by it water may be conveyed from the top of one hill to the top of another; the bend of the pipe being hid beneath the surface of the earth at the bottom of the interjacent valley. However, by reason of the downward and lateral pressure of water, the lower part of the tube must be excessively strong.

It appears that the ancients, in the construction of their aqueducts, were either deterred by the difficulty of making pipes sufficiently strong; or, they were in reality ignorant of this primary law of the gravitation of fluids: though their *Clepsydra* was on its principle. This chronometer consisted of a vessel with a tight partition in the middle. At the bottom of the partition was a very small hole. They filled one side with water; and allowance in the gradation being made for the difference in the pressure, the water falling in the one and rising in the other, pointed out the time of day. But when they wished to supply a town with water from a distant hill, they built immense aqueducts at an enormous expence. These were troughs supported on stone arches, so that the water might run along the inclined plane. Some of the great works of Solomon were of this kind;

and the stupendous ruins of the Roman aqueducts are among the wonders of the world.

The greater part of natural springs and fountains, no doubt, owe their origin simply to the gravitation of water, see Fig. 24. For, by it their waters are continually in motion, till all parts of the surface are at the same distance from the earth's centre of gravity. On this principle all rivers run into the sea; and the springs bursting out from the sides and feet of large hills, or from the summits of adjoining smaller ones, are nothing more than the rain water, collected above in the secret recesses and caverns hid within the mountain, seeking its level. For, percolating through gravel or porous earths placed beneath beds of clay, or gurgling through crevices of sloping rocks, whether at the side of the mountain or top of the hill, providing always that the aperture A be lower than the surface of the water in the reservoir B C, it will burst out to seek its level in the valley.

Though we sometimes see springs on tabular pieces of land, and near the summits of hills which are not large enough to collect the quantity of water sent forth, and which are not within sight of larger hills;—still they may be accounted for on this principle. For we are to consider, that if the top of the Alps be farther from the earth's centre of gravity than the top of Snowdon, a pipe laid from the one to the other, would equally convey water as between two neighbouring hills, though it dipped hundreds of miles below the bottom of the intervening sea. However, it is probable that capillary attraction has some share in producing some of these springs, which may be illustrated in the following manner. Having a basin half full of water, slightly twist a few threads of woollen yarn; and let one end be in the water, and the other hang over the edge of the basin. The water will slowly ascend along the yarn, and passing over the basin's edge, will fall in drops from the other end, till the basin be emptied. But this will not be the case unless the outer end of the yarn be lower than the surface of the water, and therefore it leaves the matter doubtful.

11. THE MOTION OF FLUIDS AS CAUSED BY THE GRAVITATION OF THE ATMOSPHERE.

We have already stated, that the atmosphere presses with a weight of 15lbs. on every square inch of the terraqueous globe. Water, therefore, being under this pressure, will be subject to

laws depending thereon. Hence, if we place one end of a tube in water, and then exhaust the air, a column of water will be raised up into it, by the atmospheric pressure on the surface of the other water, equal in weight to that pressure. The air, in this case, acting the same part as the weight on the upper board in the hydrostatic bellows; and, of course, it will be without reference to the tube's diameter.

Suppose the bore of the tube to be equal to a square inch, then every inch of the column will contain a cubic inch of water; and as the pressure of the atmosphere is 15 lbs. on every square inch, the column thus rising in the tube will weigh 15 lbs. Now 420 cubic inches of water are found to weigh 15 lbs.; consequently, the height of this column will be 420 inches or 35 feet.

On the above principle is the *common* pump, see Fig. 25. Within a tube that has one end in the water is a valve D, and a piston C having also a valve:—both valves opening upwards. The piston moves against the sides of the tube, and both it and valves are made air tight by means of leather kept wet with the water in the tube. This piston is worked up and down by a powerful lever at A, the pump handle. To make room for the descending piston, the air or water rushes through the upper valve, which, when the piston is drawn up, closes; and the piston leaves a vacuum beneath in the tube, into which the remaining air or the water rushes through the lower valve. If the piston descended to the surface of the water and rose again to the elevation of 35 feet, leaving no air beneath it, the water would at the first stroke rise to that elevation. But as the piston is generally confined to a box D B, or a part of the tube made wider than the rest to admit the working of the valve, many strokes are necessary to exhaust the air before the water can ascend to the piston. However, it will at every stroke rise a little, where it is retained, while the piston descends, by the lower valve; so that the remaining air will still have the same density as the external air. The operation of common pumps, or as they are sometimes called, *sucking* pumps, is very limited; since, they can only raise a column of water equal in pressure to that of the atmosphere, or 35 feet in height; and on account of friction, elevation of the pump above the level of the sea, or a diminution of atmospheric pressure as immediately before a storm, sometimes not higher than 28 or 30 feet.

Sometimes both valves are beneath the surface of the water in the well;—the piston being attached to the end of a long rod.

It then becomes the *lifting* pump; for, the water may be lifted to any height above the piston, providing the lever be worked with sufficient force, and the rod communicating with the lever and piston be sufficiently long.

A *syphon*, Fig. 26, is an hydraulical instrument, consisting of a bent tube with legs of unequal length. It is chiefly used for extracting liquids through the bung hole of casks; and depends for its action on the pressure of the atmosphere. The short leg is placed in the liquor; so that, the orifice of the longer one outside is always lower than the liquor's surface A B. Should the air be exhausted while in this position, the liquor will fill the tube and flow through it till the whole be drawn off. For the purpose of exhausting the air from the tube, a small pipe bent upwards is inserted into it, near the end of the longer leg, or so, that the place of insertion may always be lower than the surface of the liquor; for, this place, with respect to the air, must be considered as the real orifice. The short leg being in the liquor, and the end of the longer stopped with the finger, the air is sucked out by the pipe: or, without this pipe, if the syphon be first filled with the liquor, and then stopped at each end till it be properly disposed for running, the effect will be the same. Though syphons may be constructed on a larger scale; yet, since they are but a variation of the common pump, their use is limited within the elevation of 35 feet.

What are called *intermitting springs* are natural syphons. Reservoirs in the bowels of the earth are filled at different seasons; and when the surface of the water rises to a certain height, as to B C, Fig. 24, it is above the top of the syphon D; and, on the simple principle above explained, it sets a running all the syphons which chance to be there formed by a peculiar construction of rocks or dykes. The water being once put in motion, is kept running by the atmospheric pressure till the surface of the water in the reservoir is on a level with the lower orifice of the syphon, when all at once it ceases, and the fountain becomes dry without any previous notice. Though to produce this effect, we must suppose the natural syphon to be air tight; or, the fountain would cease when the surface of the water was at D. Some springs ebb and flow with the tide, and some the contrary; but all are supposed to act on this principle. Those that ebb and flow contrary to the tide, probably, have their waters delayed in the passage.

Tantalus' Cup, a toy for children, is on this principle. It

consists of a small image placed in a drinking cup. Inside the image is a concealed syphon. The cup is then filled till the water touches the under lip of the image; when, at the same time, rising above the bend of the syphon, it is immediately set a running, and is conveyed to another part of the cup. The caitiff, as the heathen poets relate, having grievously offended the gods, was condemned to perpetual hunger and thirst in Tartarus; and to increase his torment, is for ever *tantalized* with the most delicious viands and drink touching his lips, but which he cannot get into his mouth.

CHAP. VI.

The Mechanical Effects of Caloric.

1. Caloric defined. 2. Caloric the cause of Fluidity. 3. The Expansion of Bodies by the presence of Caloric. 4. Instruments for measuring Temperature, and specific Caloric. 5. Combined Caloric and Cold. 6. Radiation and Reflection of Heat. 7. Transmission and the conducting of Heat. 8. The peculiar laws of Water. 9. The Mechanical Properties of Steam. 10. Evaporation. 11. Wind. 12. Atmospheric Temperature and Climate.

1. CALORIC DEFINED.

Heat is the cause of the well known sensation we feel, or the effects we see produced by the agency of the solar rays or by the presence of fire. But as heat operates at a distance from its source, the substance of it must be in an active state, and the term heat will, therefore, convey the idea both of a substance and its action. And as this substance is likewise found in all bodies in a quiescent state or where it produces none of the effects attributed to heat, it was necessary for the sake of precision in language to make use of a word indicative of the substance alone:—hence the term *caloric.*

Caloric, then, is the substance of heat; and when at rest in any body is called *combined* or *latent* caloric; *fire* is both heat and light produced where caloric is generated, set at liberty, or put in motion; *combustion* or *burning* is the process by which the motion is communicated, or it is the dissolution of those bodies, which contain either the caloric or its component elements; *heat* is the effect or sensation produced by caloric in

motion, and is sometimes called *active* caloric; and *temperature* signifies the quantity in motion.

There are two very obvious and peculiar properties belonging to caloric; viz. it is *inconfinable;* that is, its entrance into a body and its escape from it cannot be prevented; and it is *imponderable;* for, how much caloric soever a substance contains, its presence adds nothing to the absolute weight of that substance, though in all cases it diminishes the specific gravity.

2. CALORIC THE CAUSE OF FLUIDITY.

Caloric is diffused throughout all nature; no substance is found without some portion of it, nor can any particle of matter be entirely deprived of it. To its presence we owe two of the three grand divisions of the earth's surface; viz. the *fluid* and the *æriform.* The less caloric a body contains, the more dense or contracted is its bulk. Increase the quantity of caloric in any solid, and you convert it into a fluid; increase it still more, and you have an æriform; increase it yet more, and nothing can resist its expansive force. Caloric, then, we find to be the cause of repulsion, the antagonist of attraction, or the agent that dissolves this band of nature. In *solids* the cohesive power is greater than the repulsive power of the caloric therein present, in *jelly* the attraction of cohesion and the repulsion of the caloric are in a state of equilibrium; in *fluids* the cohesion is overcome by the repulsion, which now equals the attraction of aggregation; but in *æriforms,* the repulsion exceeds all the modifications of attraction, except that of gravitation.

With respect to latent caloric, it becomes as much a component part of that body wherein it exists, as any other of its ingredients; and it cannot be extracted from it without changing the form, or making it a different substance. Water, for instance, deprived of a certain quantity becomes ice, which at the poles is as hard as any of the rocks; for even at 30 degrees from the poles no edge tool can cut it; and it is reducible to a dry powder dispersible by the wind. In Russia, at Prince Gallitzin's marriage, 1739, a house with two apartments was built entirely with blocks of ice. It also contained furniture of the same material; and icy cannon were fired in honour of the day, which performed their office more than once without bursting.

Æriform substances are of two kinds:—one wherein the ca-

loric is active, and the other wherein it is latent; the former is called *vapour* and the latter *gas*. Vapour is such a substance as may be condensed or destroyed by cold, that is, the heat on which the æriformity depends will quit it for other substances that do not contain so much caloric; and the water or whatever else was converted into vapour is restored. But under certain circumstances the caloric becomes so combined with some substances, that no cold produces any effect upon them, more than somewhat increasing their specific gravity. They are then distinguished by the term GAS. However it will be seen in chemistry that this property is rather to be attributed to the caloric itself being decomposed, than to its becoming latent as caloric. Steam from boiling water is vapour; and atmospheric air is a mixture of gases.

3. THE EXPANSION OF BODIES BY THE PRESENCE OF CALORIC.

IT is found by experiments that all substances dilate or expand by heat; also, that the more a body is cooled the less space it occupies. From this it is evident, that all the particles of which a body it composed approach nearer to each other by the loss of caloric, and recede to a greater distance by new acquisitions of it. Indeed some philosophers, in treating of attraction and repulsion, have demonstrated that the mutual attraction, existing between particles of matter, acts only at a certain distance; and that within this distance repulsion exists so as to prevent absolute contact: consequently, the particles of no substance, even of the most solid, touch each other. Hence it has been asserted, that the whole matter of the universe might be compressed into the space included by a walnut shell. However, it may probably be no easy matter for a young philosopher, though science admits the fact, to comprehend how particles of matter can compose a hard flint-stone, and yet allow of space between them.

Some substances are found to expand much more by the presence of caloric than others. Iron is more expansible than wood, and wood than stone or glass. Of the metals, platina dilates the least and lead and zinc the most. In fluids, mercury is found to be the only one that expands equal degrees with equal portions of heat;—it is, therefore, the most proper for thermometers. But liquids in general expand more than solids,

and æriforms much more than liquids. Alcohol is more expansible than oils, and oils in general more than water. Nearly all the æriforms expand alike when heated to the same degree; 100 parts of each at the freezing point of water become at the boiling point about 137·5: 100 mercury under the same circumstances become 101·835. Zinc 100·308. Gold 100·094. Platina 100·087. Glass 100·083.

It has been observed that the steel pendulum of a clock expands so much by every 4 deg. of temperature as to cause the clock to vary one second per day; and that the difference of the going of a clock in summer and winter is daily, on this account, about 6 sec. On this principle Harrison constructed his self regulating timepiece, wherein metals of different dilative properties are so disposed and adjusted as to counteract each others effects; and thus make a clock or any other chronometer go at the same rate in all temperatures.

A great many natural phenomena depend upon the expansion of bodies by heat, such as the circulation of water in the sea, evaporation, and some winds. But water has a wonderful law, in this respect, altogether peculiar to itself; which is attended with such astonishing utility as is alone sufficient to stamp the signature of infinite wisdom and benevolence on the contrivance. See s. 8.

4. INSTRUMENTS FOR MEASURING TEMPERATURE AND SPECIFIC CALORIC.

The *Thermometer*, Fig. 27, is an instrument for measuring temperature, or that quantity of active caloric which a body parts with to, or will extract from another presented to it. It is made by putting mercury into a small glass tube, that has a bulb at its lower end, and heating it till it boils. The heated vapour flying off expels the air from the rest of the tube; and while it is in this condition the upper end is closed, or welded with a pair of hot pincers or a spirit lamp, when the tube is said to be hermetically sealed. For graduating the scale the bulb is plunged into melting ice or snow, when the mercury shrinks down in the tube, and the place whereat the surface stands is marked as the *freezing* point. It is next immersed in boiling water, and the place to which the surface now ascends is fixed as the *boiling* point. The space between these two points is divided into 108 deg. But it was afterwards found that when the bulb was plunged

into a mixture of snow and salt, the surface of the mercury fell a space equal to 32 of the above degrees below the freezing point. This point was, therefore, assumed as the lowest degree of cold or *Zero*, from which the graduated scale now commences. The freezing point is, consequently, at 32 degrees, and the boiling point of water at 212 degrees. This instrument is called Fahrenheit's Thermometer from the name of the inventor. It is the one chiefly used in England, and the one always referred to in these pages. The only difference between it and others is in the numbering of the graduated scale. In it 1·8 degrees are equal to one degree of the Centigrade Thermometer, and 2·25 to one degree of Reaumur.

The Thermometer is sometimes filled with alcohol, coloured to render its movements visible. In very intense colds alcohol is preferable to mercury; for, the latter becomes solid at 71 degrees below freezing point, but the former if pure never freezes.

The *Thermoscope*, or *differential* thermometer is filled with air and is used for very delicate experiments: æriforms more sensibly expanding than fluids. It consists of two bulbs filled with air, and connected by a capillary tube containing a little sulphuric acid. The heated body is placed in contact with one bulb,—the air of which by expanding drives the liquid towards the other bulb.

The *Pyrometer* was contrived by the ingenious Mr. Wedgwood. With it he could measure the highest degree of temperature, even as high as 32,000 of Fahrenheit. It was effected by a mixture of clays, which were found to retain some particles of water till they arrived at the above temperature; so that, as they parted with the aqueous particles they contracted, and perhaps, shrunk from a tendency to liquefaction. Since his decease the art of making them is said to have been lost. One degree of Wedgwood is equal to 130 of Fahrenheit; and the scale commences at 1077 deg. of the latter, which is the temperature of red hot iron in day light.

Temperature, as indicated by the thermometer, is no proof of the real quantity of caloric which a body contains, but only of that which it imparts to surrounding bodies. For different bodies, as will be afterwards shewn, have different capacities for caloric, so that the quantity, required for raising the temperature any specified number of degrees, varies. An apparatus called a *Calorimeter* has been invented to ascertain this specific quantity. The bodies heated to an equal temperature, as indi-

cated by the thermometer, are placed in it surrounded with ice or snow. The quantity which each one melts, in being cooled to a certain point, indicates the specific quantity of caloric it contained for the given degrees of temperature. Yet, neither this nor any other contrivance can enable us to ascertain the real quantity of caloric which a body contains.

5. COMBINED CALORIC AND COLD.

SOLIDS, liquids, and æriforms contain different quantities of caloric, which is called their *specific* caloric. The quantity of caloric in ice is to that in water as 9 to 10. If a pound of ice at a temperature of 32 deg. be mixed with a pound of water at 172, the ice will all dissolve, but the water will indicate a temperature of only 32 deg. Hence, the difference of the quantity of combined caloric in ice and water is equal to what would raise the temperature of water to 140 degrees:—this is called the caloric of fluidity.

If steam at 212 deg. be mixed with six times its weight of water at 62 deg. the steam will be condensed, and the temperature of the water will be about 212; so that about 900 deg. in this case are taken from the steam and added to the water. Mr. Watt, by heating water under the pressure of a strong iron vessel, raised its temperature to 400 deg.; but as soon as the pressure was removed, only part of the water was converted into steam or vapour; and the temperature of this steam, as well as that of the remaining water, was only equal to that of boiling water or 212 deg. As much caloric, therefore, as would raise the water 188 deg. became latent in this small quantity of steam. From these and other experiments it is calculated—that steam contains as much combined caloric more than water, as is equal to 1000 deg. of specific heat.

Different substances have various capacities for caloric. Thus: a pound of water at 100 deg. mixed with a pound at 200 deg. will produce a mean of 150 deg. But a pound of water at 100 deg. and a pound of mercury at 200 deg. will make a mixture of a lower temperature than the mean or 150 deg.,—which shews that mercury has a much less capacity for caloric than water.

Our limits of producing cold are much more contracted than those in which we can produce heat. A crystallized compound of muriatic acid and lime, dissolved in pounded ice or snow, will sink the alcohol to 122 deg. below freezing point. But this

is the lowest temperature that has been produced; while heat has been measured as high as 32,000 deg. How far the thermometer would sink, if all the caloric could be extracted from ice, we cannot tell; but as the specific quantity of combined caloric in ice is to that in water as 9 to 10, and as this one part is equal to 140 deg. so the remaining part may, perhaps, be assumed as equal to 9 times that, which would be equal to 1260 degrees.

At what degree the thermometer would stand at the poles, is not known; but in the regions round Hudson's Bay, it has been known to fall as low as 82 deg. below freezing point. When stones or metals in these temperatures are touched with any of the softer parts of the body, the heat is so rapidly absorbed that the flesh becomes instantly frozen and mortified:—the living principle being wholly extinguished. In these regions the inhabitants shut themselves up in caves, and totally exclude the external air. Should a little air break into their habitations, the moisture of their breath immediately falls as a shower of snow to the ground; and if they breathe this cold air, their lungs feel as if they were torn asunder. The most intense cold ever known in the neighbourhood of London was on December 25th, 1796, when the thermometer fell 34 degrees below freezing point.

The temperature of the human body is 98 deg. which is called blood heat. And this temperature, with very little variation, is the same in all climates, and at all seasons of the year. Any thing at a temperature above this we call hot; if equal or nearly so we pronounce it warm; and if much below, we then say it is cold. From this, and what has been said upon caloric, it is obvious that cold is not a substance, but only a mere absence of the usual quantity of heat; and that the word *cold* as well as the word *warm* are only relative terms, and frequently convey no very definite meaning; since, what we call cold at one time we frequently pronounce warm at another. As when we say of a fountain, that it is cold in summer and warm in winter; though the temperature both of the water and ourselves remain the same:—that of the atmosphere alone being changed. In summer the air conducts little caloric from our bodies, because the temperature of the atmosphere and that of our bodies are sometimes nearly equal, while perhaps that of the water is about 50 degrees; so that, when we dip our hands into it, it imparts a great sensation of cold; but in the winter, when the atmos-

pheric temperature is at or below the freezing point or 32 deg., the air will extract a great deal more caloric from our bodies than the water, which has the same temperature as in summer; and, therefore, the water will feel comparatively warm.

It is combined caloric that gives malleability and ductility to the metals; for in intense artificial colds the most ductile and malleable, such as gold, silver and lead become brittle. The quantity of latent caloric in iron is such, that when a piece is smartly hammered for a short time, it becomes red hot by reason of the latent caloric being put in motion or beaten out. Hence, by too much hammering this metal becomes brittle and loses its malleability; and having been once heated by hammering, it cannot be made red hot a second, till after it has been in a fire.

6. RADIATION AND REFLECTION OF HEAT.

UNCOMBINED caloric never rests in any substance, but is continually dispersing itself among surrounding bodies, flying off in perpendicular lines from the surface as rays of light dart from the sun or a lighted candle, and it is therefore said to *radiate*.

Different substances are found to radiate in a given time different proportions of heat. A black surface will radiate more than a white one; and one that is rough, unpolished and dull will radiate more than one that is smooth, highly polished and bright. Take a tin canister with four sides; and cover the first side with a coat of black paint; the second with white paper; and the third with a pane of glass or any thing very smooth; and let the fourth remain bright tin. Then fill the canister with hot water, and turn the sides successively towards a concave mirror with a thermometer placed in the focus; and the tin will be found to radiate the least, the black the most, and the white more than the smooth. On this principle vessels should be highly polished in which we wish to retain heat, and stoves and other contrivances for warming rooms should be coated with black paint; or if covered with black lead they should remain unpolished at the places where the heat is to be principally radiated. Lamp-black is found to radiate 100, black-lead 75, polished iron 15, and bright tin 12.

Heat is reflected from smooth and polished surfaces in the same manner as light, (see Chap VIII. s. 6); and surfaces are

found to reflect it in the inverse proportion to that in which they radiate it. Should pieces of ice be covered as in the above experiment,and exposed to the solar rays, the most will be dissolved beneath the black surface, proving that it has absorbed the most heat and reflected the least, and so of the rest. The peasants, in Switzerland, are said to cover the snow, that lays on patches of land which they wish to cultivate, with black cloth; so that the sun may the more readily dissolve it; and some horticulturists in England blacken the walls to which fruit trees are nailed, and thus obtain an increase of temperature, and greater perfection in the size and flavor of the fruit.

7. TRANSMISSION AND THE CONDUCTING OF HEAT.

THE motion of caloric through bodies is of two kinds. Through some it passes very swiftly, and is said to be *transmitted*; but through others it moves remarkably slow, and is then said to be conducted: hence, some substances are much more rapidly heated than others; and those that are the most rapidly heated are, proportionately, the soonest cooled. "If slender cylinders of silver, of glass, and of charcoal of equal length and size be held in the central part of the flame of a candle, the silver rapidly becomes heated throughout, and cannot be held in the hand; the heat is more slowly communicated through the glass; but the charcoal becomes red hot at the one extremity long before any heat is felt at the other." If a stone or a marble slab, a piece of iron, a carpet, and a book be all at the same distance from the fire, they will be all of the same temperature as indicated by the thermometer; but when touched they will produce very different sensations in the hand. Should their temperature be lower than that of the hand, the iron will feel the coldest, the stone the next, and the wood of the table, and the leather of the book back will be colder than the carpet. But if they are at a higher temperature than the hand, the iron which before was coldest will now be the hottest, and so of the rest proportionately. In the former case, the iron conducted the caloric from the hand the most rapidly, and caused the most speedy sensation of cold; but in the latter case, it imparts it to the hand the most readily, and therefore causes the most immediate sensation of heat. But should all the substances be of the same temperature with the hand, then no difference will be perceivable by the touch. Gaseous bodies are the slowest of all

conductors, and they communicate it as slowly to other bodies. The heat of metals at 120 deg. is scarcely supportable; water scalds at 150 deg.; but the heat of air at 240 deg. has been endured for some minutes in a room artificially heated.

On the above principle we put wooden handles on metallic tea-pots and other utensils, and take hold of moderately hot iron with woollen wrappers; also wear clothes made of various materials according to the weather to keep us warm. Woollen is a slower conductor of heat than calico; and calico, than linen; and therefore clothes of the first material are preferred for very cold weather. The contrivance of nature for animals as spread over the surface of the globe indicates, in this respect, the result of the most consummate wisdom and unbounded benevolence. Under the torrid zone they are clad with hair, because hair is comparatively a rapid conductor of heat, and therefore a very cool clothing; while in cold climates and the frigid zones they are invested in fur and down, the slowest of all conductors, which for that reason keep the body quite warm. At the approach of winter some animals change their colour to white, which farther increases the non-conducting power. The breasts of water fowl are closely matted with down to protect this vital part from the effects of water, which is, when put in motion by their swimming, a most rapid extractor of heat.

In general the denser bodies are the more rapidly they conduct heat. Atmospheric air containing so little matter is therefore a very slow conductor; and it is supposed that the particles of air occupying the interstices of soft and light bodies, such as are made of wool, fur, and down, prevent the heat from being conducted. If air conducted heat as rapidly as some substances do, in winter, when we are inevitably exposed to it, it would extract coloric so rapidly from our bodies as to occasion immediate death. In high northern latitudes where the cold is such as to solidify mercury, the air occasions little injury to those parts of the body exposed to it; but when metallic substances are touched, a sensation like that of burning is experienced, and the part is blistered. Windy weather is much colder than calm; for when the air is still, that in contact with the body, though warm, very slowly gives place to that which is cold; but the wind is continually dispersing it, and presenting a cold stream which rapidly extracts fresh caloric: so that while the thermometer shews no difference between a calm and a wind, the human frame is sensible of a very great one.

Water, and all fluids are slow conductors of heat; but when water is in motion it extracts it rapidly. Indeed when it is still, it is so slow a conductor, that it has been disputed whether it conducts it at all. We place a pan on the fire and heat the water till it is all hot. If water is so slow a conductor how comes this to pass? The heat enters at the bottom, and the particles of water in contact with it are expanded with the presence of caloric. Their specific gravity then becomes much less than the other particles of water in the pan, and they immediately rise to the surface. Colder ones then come in contact with the bottom, and suffer the same fate. This succession and alternation go on till the whole arrives at the temperature of boiling water or 212 deg. Here, then, the circulation ceases till the particles at the bottom have taken in their 1000 degrees of latent caloric, when they become suddenly expanded, and occupy 800 times their original space; but they are then 800 times lighter, and they come rapidly to the top in bubbles and fly off. In their ascent from the bottom of the water to the surface with their bulk thus enlarged, they occasion that bubbling motion which we call *ebullition* or *boiling*. Was it not that each succession of these particles has to remain at the bottom to combine with the 1000 degrees of specific caloric, as soon as the boiling commenced the whole of the water, instead of taking a long time to evaporate or boil away, would be at once precipitated from the pan.

Should the heat be applied to the surface of the water the result would be very different. The expanded or light particles will not descend. Water has been evaporated by heat applied to the surface of a pan of water, while a cake of ice remained unaltered at the bottom. However, this only proves that water does not conduct heat so rapidly as might be expected from seeing it on the fire. If evaporation be prevented by heating water in a close vessel, the heat will be conducted nearly in the same manner as in solid bodies of equal density; and water may thus be made red hot; but as long as the surface is open the vapour carries of the caloric, so that it is impossible to raise the temperature of the water in an open vessel higher than 212 degrees. When large boilers are to be heated with steam, it is always necessary, therefore, to apply the steam to the bottom of the vessel.

The water of the ocean regulates the extremes of atmospheric temperature. It is ascertained that the summer heat never

never penetrates deeper into the earth's surface than from 15 to 20 inches. But it is not so with the troubled mass of waters in the mighty ocean. In summer the temperature of the sea is always lower than that of the atmosphere, and therefore the water rapidly absorbs the caloric from the contiguous air; and by the agitation of the tides and other causes, the warm and the cold water is blended even to the depth of the ocean. But in winter the temperature of the sea is very often above that of the atmosphere:—in this case the latter absorbs caloric from the former, and a circulation takes place in the water. The particles at the surface, having lost their caloric, descend to the bottom, and warmer ones ascend; and this continues, with certain limitations, throughout a great part of the winter. Hence, near the sea the air is always cool in the hottest day of summer, and snow never continues long upon the ground in the coldest part of winter. It is supposed that a continual interchange between the waters of the oceans lying under the torrid and frigid zones is constantly going on; and that many of the currents, found in the intervening seas, are thereby occasioned. The stream from the Gulf of Mexico, called the gulf stream, is found among and northward of the Bahama isles 1000 miles from its source, to increase the temperature of the sea.

8. THE PECULIAR LAWS OF WATER.

If we place before the fire a vessel filled with pounded ice or snow with a thermometer in it, the mercury will gradually rise to 32 deg. and there make a stand; and though the ice is still receiving new accessions of caloric, the thermometer will rise no higher till the whole of the ice is melted, or till it has acquired the 140 deg. of specific heat, when it will begin to rise gradually as before. From this, it appears, that ice contains much less absolute heat than water of an equal temperature; and in this peculiar circumstance we have a wonderful display of infinite wisdom in the contrivance of the Great Creator. For if ice or snow had melted as soon as it attained the temperature of 32 deg. without any further acquisition of caloric, when the atmosphere in the spring arrived at that temperature, the whole mass of snow deposited during the winter in cold regions would have almost instantaneously dissolved, and carried a deluge along with it.

While every other substance in nature expands, as its temperature is increased from the lowest point to the highest; and diminishes in bulk, as the temperature is diminished from the highest point to the lowest;—*water* alone has its own peculiar laws, and forms an exception to this general rule. Its greatest density is at 42½ deg.: and whether it is heated a certain number of degrees above, or cooled a corresponding number below, it expands,—and that in equal degrees. This is another wonderful contrivance of Infinite Wisdom; for, if water still continued to contract its bulk or increase its density when it was cooled below this temperature of 42½ deg. the cold particles of the surface would descend to the bottom, and the whole mass of water on the face of the earth would become one body of ice, which no summer's heat could dissolve. But by this simple contrivance the circulation ceases when the water is cooled as low as 42½ degrees. And when it is cooled to 32 deg. the freezing commences with the particles at the surface. At the moment that any part is congealed, the caloric of fluidity or 140 deg. of specific heat is given out to the air above and water below; and a sheet of ice, which is a bad conductor of heat, being now interposed between the water and the atmosphere, the process of congelation proceeds very slowly; especially as the ice must now be formed beneath the sheet, that prevents the escape of the caloric of fluidity to the cold air. Sea water does not congeal till it is cooled down to 28½ deg., or 3½ deg. below the freezing point of fresh water; and here we have a continual source of caloric to the atmosphere, when all other parts of the earth's surface are bound up. This is one advantage resulting from it, besides the more obvious one in a commercial point of view.

When the atmospheric temperature descends below the freezing point, the vapour that is hovering in the air becomes congealed; and the frozen particles, descending to the earth, come in contact with each other and form flakes of snow. During this congelation a great deal of caloric, viz. that of fluidity, is set at liberty from the vapour; hence, we generally, and always when there is no wind, find it warmer after a fall of snow. See Chap. XVI. s. 10.

Water in freezing crystallizes in filaments, which are uniformly joined at right angles of 60 or 120 deg. These leave interstices between them supposed to be filled with air, of which water is known to contain a considerable quantity. Ice, there-

fore, occupies a larger space than the water from which it was formed, and this increase is nearly equal in fresh water ice to about one part in 15 of the water; the specific gravity therefore of ice to that of water is as 15 to 16; consequently a piece of ice will always swim, and that with one-sixteenth of its bulk above the surface of the water, and the other 15 below. But ice formed from sea water, though it contains no salt, has a less specific gravity: being to that of the water, as 9 to 10. The extent of ice bergs are guessed at on this principle; some of which, in the neighbourhood of Hudson's Bay, have elevated their heads 5 or 600 yards above the surface of the sea.

Water, while freezing, expands with a force that nothing can resist. The expansive power of one cubic inch will raise a weight of 14 tons. A cannon was burst by being filled with water, and exposed to the frost with its vents properly secured. In large rivers around Hudson's Bay, the ice is sometimes broken by the expansion of that beneath while in the act of forming; rocks are uplifted in confused heaps, and beams in the houses are split with loud explosions. In severe frosts, even in our own climate, trees are often split; and huge masses of rock, thus rent, are frequently tumbled down from the craggy tops of high mountains, carrying terror and devastation along with them. In the same manner frost lightens the surface of the earth. Water, having penetrated the glebe, expands in freezing, and destroys the adhesion among the terrene particles; so that when thaw succeeds the soil is pulverized. Vegetables, all of which contain some water, suffer in frost by the expansion of the water destroying their texture. However the aqueous particles are so thinly dispersed in plants, that if they be very slowly thawed, as by carefully sprinkling cold water upon them before the sun rises, they will suffer very little.

It is a wonderful provision of nature, that the water held in solution in the air should congeal and descend as soon as the atmospheric temperature is below the freezing point. For the snow, by its gentle descent, is laid so lightly upon the earth as to include a great deal of air; and as air is a very slow conductor of heat, it acts as a warm carpet. Snow never cools lower than the freezing point; and as the earth is only at this temperature when the snow descends, consequently, it remains so even at the lowest atmospheric temperatures; and in Russia the thermometer will sometimes fall 70 deg. below the freezing point. Here we see how provident the Author of Nature is for all her

productions. By this simple contrivance, when the thermometer indicates such a temperature as would, were they exposed to it, destroy the roots of all the tender plants with which the earth is in spring and summer bedecked, she is enabled to cover them up, and, as a hen gathers her chickens under her fostering wings, preserve them with a parental care in a place of comparative warmth.

9. THE MECHANICAL PROPERTIES OF STEAM.

If we place upon the fire an open vessel of water with a thermometer in it, the mercury will rise gradually to 212deg. but no higher: all the fresh acquisitions of caloric, afterwards derived from the fire, become latent in the steam. By the presence of this caloric the water now taking the æriform state is increased in bulk 800 times. But if this steam is confined, and still heated to 3 or 400 degrees, it will require a space to expand in equal to 1400 times that of the water; and what is very remarkable in this case, it does not impart any sensation of heat to the hand. The workmen are under no apprehension of being injured by steam under a pressure of this temperature; whereas at 212deg. it would scald dreadfully. No satisfactory solution has been given of this phenomenon; most probably, as this is the bulk of its component gases, the water is decomposed into its elements, and the caloric into its electric fluids; when the negative electricity of the caloric unites with the oxygen of the water to form oxygen gas; and the positive electric fluid combines with the hydrogen to form hydrogen gas.

It was once said that water was incompressible and without elasticity. The Florentine academicians filled a hollow globe perfectly full of water, and submitted it to a very powerful pressure, even till the water oozed through the pores of the metal and stood as dew upon the outside; but there appeared no diminution of bulk. However it is now found to be compressible in a very small degree. At the depth of one hundred miles, it has been calculated that its density would be double: and at twice that depth quadruple. But steam is very compressible and very elastic; that is, it may, like atmospheric air, be forced into a less space; but while the temperature remains the same, it is always ready to expand with the same force that compresses it.

A cubic inch of water will expand into 8 or 14 hundred cubic

inches of steam; and a cubic inch of gunpowder will make 1000 cubic inches of elastic æriform substances; but water raised into steam is said to be 28 times stronger than gunpowder; that is, if an ounce of gunpowder, fired, will raise a weight a certain height and hold it there, the same quantity of water converted into steam would raise 28 times the weight, and suspend it at the same height: or an ounce of steam by its elasticity will give a ball as much momentum as 28 ounces of gunpowder.

The *Steam Engine*, "The triumph of mechanics, and the most valuable present philosophy ever made to the arts," is an application of this expansive force of water, while assuming the æriform state by its union with caloric, to the impulse of machinery. It consists of a large boiler in which the water is exposed to the heat. A tube communicates with this boiler and a cylinder. Within the cylinder is a piston which fits so accurately that no steam can escape; yet so, that it may move freely up and down. By means of a valve or stop cock that opens and shuts with the machinery, a little steam is admitted into the cylinder beneath the piston, which by its expansive force gives the piston the upward stroke. When it has risen to a certain height, another valve is opened, which permits the steam to escape into a large cooler where it is met by cold water and condensed, so that the piston falls. But at the same time that this last valve opens for the escape of the steam below, another valve opens above, that admits steam into the cylinder on the upper side of the piston and gives it the down stroke. By this means a rod fixed to the piston is moved up and down in a rectilineal direction, and, being attached to a horizontal beam that works in the manner of a lever, it communicates motion to the whole machinery.

The power of steam is not limited. It performs, provided the machinery and heat are proportionate, the work of one horse or that of a thousand with the same ease. In a well constructed engine, where the steam is permitted to escape, a bushel of coals will do the work of ten horses for an hour. In some engines on a small scale alcohol is used; and as its vapour is not allowed to escape, a small quantity will serve a long time; and being raised into vapour at a less temperature than water, there is a considerable saving of fuel.

When a very great power is required, as when water is to be drawn out of very deep mines, steam heated to above the usual temperature of 212deg. or till the water expands to 1400, is sometimes used. These are called *high pressure engines*; and

are very dangerous:—it being difficult to manage the safety valves and construct the boilers of sufficient strength.

10. EVAPORATION.

THOUGH water evaporates so rapidly, when raised to the temperature of 212 deg.; we are not to suppose that this is the only time when it assumes the æriform state. It evaporates less or more at all temperatures above freezing point, or when the temperature of the surface of the ground is higher than that of the air; and this it generally is in the day time, especially if the sun shine. For it is found that the rays of the sun do not produce heat till they meet with a proper medium; so that in the hottest day of summer, at an elevation of less than two miles, the thermometer would fall to the freezing point. It is also found that a cubic foot of atmospheric air, at a temperature of 60deg. has a capacity for, or will hold in solution 11 or 12 grains of water dissolved in vapour; though it is seldom found, principally for want of temperature, to contain more than 5 or 6 grains. The rays of the sun, then, concentrated at the earth's surface, which is a proper medium for producing heat, raise its temperature and that of the contiguous air, considerably above the temperature of the more elevated air; and the caloric, combining with the particles of water, gives them the repulsive property or expansion of bulk essential to vapour, and causes them to ascend. Evaporation will, therefore, be regulated according to the quantity of vapour already in the air, for it only takes up vapour according to its capacity. In a calm day the stratum of air next the earth's surface becomes filled with vapour, and the process is slow; but when there is a brisk gale, this stratum is blended with the rest, and a comparatively empty portion is continually presented; so that the work of evaporation proceeds apace.

The quantity of water evaporated in a dry, hot summer's day, is equal to a sheet of one fifth of an inch in thickness. Bishop Watson calculated, from experiments made by inverting a large drinking glass over a close mown grass plot, and carefully collecting the vapour attached to the inside, that an acre of land, even when the earth has been long parched with drought, will, emit in twelve hours of a summer's day, in the state of vapour 1,600 gallons of water. In the temperate zones, about four times as much is evaporated in the summer half year as in the winter

half. From experiments made at Liverpool and Manchester, it appeared that 36¾ inches were annually evaporated at the former place, and only 25 inches at the latter. Liverpool being on the sea shore will have much more rain than Manchester, which circumstance will, perhaps, account for this disparity. From the sea and inland sheets of water, it has been said that evaporation is frequently six times greater than it is from the land.

The evaporation in the torrid zone is much greater than in any of the other zones; so that 35 inches have been assumed as the mean depth of water evaporated from the whole surface of the globe. This will give 94,450 cubic miles of water, which are annually raised into the atmosphere; and which must descend in dew, rain, snow and hail. If this prodigious mass of water was to remain in the air all at once, it would increase the atmosphere about one-twelfth, and raise the barometer about 3 inches. But as a day never passes without rain in many parts of the earth, so the atmosphere is continually discharging its load. It is calculated, that the atmosphere, under the torrid zone, seldom contains more vapour than is equal to six-tenths of an inch of mercury in the barometer; and that, with us, it rarely exceeds five-tenths in summer; and one-tenth is assumed as the average quantity in winter. Though we say that atmospheric air has a capacity for vapour; yet it always increases the extent of any portion of air by the whole measure of its own bulk; and being lighter than atmospheric air, in the proportion of 10 to 12; it, therefore, ascends till it arrives at a place of its own density, and is there collected into clouds by electricity; though it frequently remains dispersed, and is then invisible.

As a proof that evaporation exists to the extent we have assigned to it, the Mediterranean is supposed to lose by it, all the water it receives by the Dardenelles from the Black sea; into which the Danube, the Neiper, the Neister, the Bog and some other rivers empty themselves. Besides these are the Nile the Po, the Tiber, the Rhone, and several other minor rivers all emptying themselves into the Mediterranean; the waters of all which, even for the supply of all these rivers, must again evaporate. There is also a strong current from the Atlantic through the straits of Gibraltar into the Mediterranean; but it seems doubtful whether there is not a counter current beneath the upper one, from the Mediterranean into the Atlantic. However leaving this point undetermined, the ocean under the tor-

rid zone must hourly impart its millions of gallons to the heated atmosphere.

Many important operations depend upon evaporation. By it, the produce of the earth is brought into a fit state for laying in store for the winter; corn is dried, hay is made, and fruit is matured; and among the common conveniences of life depending on evaporation, is one of no small importance, viz, the drying of our clothes after they have been washed.

Evaporation, as we have already said, carries off vast quantities of caloric. By it a man may be frozen to death in the hottest day of summer;—the hotter the day, the quicker the process. For, by dressing him in flannel moistened with ether, and exposing him to the rays of the sun, at the same time sprinkling him with more ether, the evaporation will be so rapid, and the quantity of caloric, extracted from his body to form the vapour, so great, that he will be shortly deprived of that portion of vital heat essential to existence. The experiment may be less dangerously tried by wrapping a bottle of water in lint dipt in ether and exposed to the sun, when the water will soon be frozen; but more speedily so, if the bottle be first scratched with a flint-stone or diamond.

The loss of heat, by evaporation, is very beneficial to mankind, especially to the labouring classes;—for, was not the caloric dissipated by perspiration we should faint, or die of excessive heat under any great bodily exertion, Hence, we often feel very uneasy, or a feverish sensation of heat a few minutes previously to perspiration; especially if it is produced by a sudden transition from a cold to a heated atmosphere, or by sudden and violent exertion. Persons in a fever never perspire, or if they do it brings relief.

Labouring people, exposed to the heat of the sun or that of large fires, find much relief from drinking copiously of water or any other dilute beverage; for, the more they drink the more profuse is perspiration; and, consequently, the greater is the quantity of caloric carried off from their bodies. On the same principle water quenches fire. The water being raised by heat into vapour; and the vapour requiring such a quantity of caloric with which it combines and flies off, that the fire is dissipated. But for reasons that can only be explained on chemical principles, a very small quantity of water will rather increase the raging of fire than restrain it:—the experienced fireman is

well aware of this, and never directs the water from his engine to the hottest place.

In India and China the wealthy have their houses for summer residence open at the sides:—the roofs being supported on pillars. Curtains are substituted for walls, which their slaves continually sprinkle with water; so that a constant evaporation is kept up, that carries off the internal heat, and the apartments are rendered cool and refreshing. Vessels, called by the Spaniards acarrazas, made of porous earth are now used for cooling wine. They are first steeped in water, with which the porous materials become saturated; the wine with the bottle is then placed inside the empty vessel, when the water, evaporating, carries off the surrounding heat. A person sitting in wet clothes catches cold by the water carrying off too much vital heat; could he, in such a condition, be cased up so as to prevent evaporation, it is supposed he would receive no injury.

As steam thus carries off heat, so does it as faithfully conduct it, and carefully deposit it in any place required. It is now employed in a vast variety of operations, with a great saving of fuel, and without any hazard from fire. Steam will heat nothing hotter than 212deg.; so that, in several of the arts, such as making gunpowder, or where oil is to be used at the hazard of boiling over, in drying malt, heating large boilers (20 or 30 of which may be kept at a boiling heat by the steam of one boiler,) or even in cooking by what are called steam pans or kitchens, it is of the greatest possible utility; and in a short time as prejudice gradually gives way to reason, will no doubt be rendered more generally useful.

11. WIND.

WIND is the motion of the atmospheric air, either forced from its equilibrium or endeavouring to regain it. There are three principal causes of wind; viz. *first*, rarefaction by heat or the presence of the sun's rays, and the consequent condensation by cold or their absence; *second*, the loading of the air by evaporation, and the vacuum caused when the vapours are precipitated in rain, (see Chap. VII. s. 8); *third*, Electricity, (see Chap. XVI. s. 11). The winds depending on the first cause are regular; but those depending on the other two are irregular.

Wind in our climate is proverbially *uncertain*, and its origin very difficult to ascertain; but however this latter may be, the former only applies to some regions of the earth; for, within the

tropics or even as far as 30 deg. each side of the equator, and in some countries, at certain seasons, to a much greater distance, the European adage might be inverted into, "as certain as the wind" so determined are its periodical changes. These are the winds depending on the heat of the sun; and they always blow, either from east to west, or from a colder to a warmer region.

Atmospheric air is known to expand considerably by heat; therefore, that part on any given portion of the earth's surface where the sun is vertical, will be greatly heated and expanded every day when the sun comes to the meridian, and its specific gravity diminished in the inverse ratio of the expansion. It cannot displace the lateral colder air; but, on the contrary, will be displaced by it, and must consequently rise upwards: the cold lateral air taking its place. There will, therefore, be a strong current of the cool air from all sides to the heated part of the earth's surface. Now as the progress of the sun over the earth's surface is at the rate of about 1000 miles per hour; and the swiftest wind, even that of a hurricane, is calculated to move only at the rate of 100 miles per hour; consequently, the sun's motion will be too rapid for the air to rush into his rarefied path from the western side. But as his motion is thus westerly, with perhaps a slight attraction of both sun and moon similar to that causing the tides, the atmosphere will have a westerly motion. However, as attraction acts according to the quantity of matter, and the whole weight of the atmosphere is only equal to a depth of water of 35 feet; the motion of the atmosphere occasioned thereby, cannot be very great, especially as the principal part of it is very near the earth's surface, and, therefore, cannot, as has sometimes been asserted, have any material augmentation of attraction, by being nearer the sun or moon.

To have a right notion of these winds, we should conceive a circle on the face of the earth, whose diameter extends over about 14 deg. of the earth's surface; the sun always vertical over its centre; and the circle bisected by a meridian passing through the sun. Then, the semicircle eastward is that wherein the air is always in motion, radiating towards the centre from this semicircumference. At the southern side, the wind, though small, will be from the south; at the S E point, from south east; at the quadrant or E, full east; at N E, north east; and at N, the wind will be from the north. The strongest rushing in of the cool air may, therefore, be from the S E and N E; since at full N and S, the air will, on account of the sun's velocity,

hardly be put in motion; and the eastern wind will be disturbed or counterbalanced by the lateral conflicting currents. But as this semicircle goes westward with the sun, the lateral winds will partake a good deal of the same direction.

As the sun is never vertical two days together over the same place, being at the tropic of cancer on the 21st of June, and at that of capricorn on the 21st of December, 47deg. distant; in summer his direct rays will not much affect the air of the southern latitudes; and in winter they will not much disturb that of the northern. But as the sun, at certain periods of the year, passes twice over all the places between the tropics; consequently, when he is at the equator, for 7deg. north, there will be a north-east wind; most easterly in the first and second degrees, and most northerly in the sixth and seventh. But when the sun is at 7deg. north of the equator, those same 7deg. of north latitude will have a south-east wind. The same may be observed of any other parallel of latitude at which ever the sun is vertical. The regular easterly wind is called the *trade* wind; but the variable S. and SE. N. and NE. are the monsoons; and they regulate the navigation in the tropical seas.

But though the above may be considered as the primary trade winds and monsoons; yet, there are other secondary ones, which considerably affect their course; sometimes blowing in the same direction, when they seem to extend the limits of the primary; sometimes in an opposite direction, as the one or the other prevails, or they occasion a dead calm; and in other places their directions are at right angles to each other: yet, upon the whole, their deviations are as certain, and as well known as the direction of the main wind. These winds originate in the difference between the temperature of the earth's surface, and that of the sea; the former being much more heated by the solar rays than the latter. When these winds are on a small scale, they are called *land and sea* breezes; but when on the large, they are confounded with the trade winds and monsoons.

In islands under the torrid zone, and to a certain distance from the shores on the continents in the temperate zones, the earth's surface, in the day time, becomes many degrees hotter than that of the sea; the air is, therefore, considerably expanded; and about ten o'clock in the forenoon the cool air from the sea begins to rush in to supply the place of the rarified air, which is thus pressed upwards. But on the contrary, as the nights under the torrid zone are much longer than the summer nights

of the temperate zones, and as land cools more rapidly than water, its surface, during the night, becomes of a lower temperature than that of the sea; consequently at about 6 o'clock in the evening the sea breeze ceases; and about 7, it begins to blow from the land to the sea, and continues to do so till about 8 o'clock in the morning, when it dies away. These land and sea breezes are always considerable under the torrid zone; and, in hot summer weather, they extend even as far as Norway; but they depend a great deal on the neighbourhood of hills; and, therefore, seem a little affected by electricity or the *third* cause of winds. They greatly moderate the temperature of our summers, especially on the sea shore; hence, our sea-bathing places become crowded with persons, whose circumstances will allow them to enjoy this refuge from the enfeebling heat of inland situations.

But in the large and burning continent of Africa, and partly on the continents of Asia and America, as well as on the extensive island of New Holland, the interior becomes so heated, that it retains through the night a higher temperature than the sea. Hence, at all seasons of the year there is a constant wind on certain coasts towards the interior. For instance, on the eastern coast of Africa, from 4 deg. N. lat. to 4 deg S. lat. the wind is always from the south-east to south; but in the same latitude on the eastern coast of South America, it partakes a good deal of the easterly;—thus pointing to the central part of each continent. In the same latitude on the western coast of Africa, but extending farther northward to the Guinea coast, the wind is, for the same reason, from S. to S W. On the north-west of this tract, or at such a distance beyond the most westerly point of Africa, that the heated interior of this continent should cause a westerly wind, and the course of the sun should cause an easterly wind, we must expect that these causes will counterpoise each other; which we actually find to be the case. For, between the parallels of 4 and 10 deg. north latitude, and the longitude of the most eastern of the Cape Verd islands and Cape Verd, is a tract subject to perpetual calms with thunder and lightning, and such constant rain, that it is frequently designated by the name of "The Rains." Ships, within these 6 deg. of latitude, have sometimes been detained for months, suffering all the horrors of famine.

Near the tropics, and in countries extending a long way into the temperate zones; the wind, for about five of the hottest

months, blow continually from the sea towards the land; and in the five coldest months, from the land towards the sea. The two intervening months are subject to calms with thunder and lightning, and occasional hurricanes, in which the wind generally blows from all points of the compass. These land and sea breezes, then, according to the nature of the coast, and the situation of the country with respect to the adjoining seas, as well as the extent both of the continent and sea, must blow in many and various directions when considered with reference to the whole globe; but with respect to each coast, they are as regular as the primary trade wind and monsoons; and all their changes are as well known to mariners.

While the heat of the sun thus lifts, as it were, the atmospheric air beneath him, and permits the circumambient cool air to rush in and supply its place; the exalted air must, in the higher regions, soon regain its equilibrium of temperature, and flow in the direction of the poles to supply the place of that rushing towards the torrid regions. This might be expected to produce effects in the other zones as decisive as those in the torrid zone; and when a ship gets out of the limits of the trade wind, she invariably meets with a wind blowing in a contrary direction. However, most of the atmospheric currents in the greater part of the temperate zones, and all those of the frizid zones, are too variable to be attributed to this cause. Besides, these winds never amount to storms, whose origin, as well as that of many breezes all over the globe, must be sought for in the *third* cause of wind.

12. ATMOSPHERIC TEMPERATURE AND CLIMATE.

We stated, Chap. II. s. 10, that the earth is above three millions of miles nearer the sun in winter than in summer; yet the difference of atmospheric temperature of the two seasons would induce the reader to draw an opposite conclusion; and it, therefore, seems necessary that we should explain this paradox. If the heat of the sun depended upon his proximity, then it would be hotter in the summer of the southern hemisphere than in that of the northern; but this does not appear to be the case; and therefore the eccentricity of the earth's orbit seems to have no effect on the atmospheric temperature; or if it has, it is lost in other causes of variation. The solar rays produce the most heat where the sun is vertical; and the least where he is at the

greatest distance from the zenith. This may be shewn by dividing the diameter of a circle into any number of equal parts, suppose twenty, and considering it the earth's axis or the terminator. Then, by drawing lines from each of these divisions, converging towards the sun at some distance, either at the tropics or equator, it will be seen that the arcs of the semicircle included between the lines will differ greatly in length. If therefore these lines be considered as solar rays, and the circle the earth's surface, then it will be obvious that the solar rays fall the densest where the sun is vertical. It may be farther exemplified, by holding a flat surface or a plane perpendicularly to the hearth before the fire, to represent the vertical or direct rays of the sun, when the surface will soon acquire a burning heat; but if it be held at different angles, so that the radiating heat may strike the plane obliquely; a point at the centre, though that point be at the same distance from the fire as when the plane was vertical, will indicate very different temperatures according to the angle, or the obliquity of the impinging rays.

Another cause of variation in atmospheric temperature, is, in the difference of the length of day and night:—this is considered as the foundation of what is meant by climate. In summer, the sun, for about six weeks, never sets within the north frigid zone; and in winter he never rises in all that time. During one part of summer, in England, the sun is above the horizon 16 hours in the day, and only 8 hours below it: but in winter this is reversed. The earth's surface, during the night, loses a great deal of the heat it acquired by day. The difference of temperature at London between the day and night, is, in January 6 deg., in July 10 deg., in September 18 deg. But where the sun is a shorter time beneath the horizon, the earth cools less. Within the frigid zone, where he never sets, the atmospheric temperature, from the 10th of May, when the sun has 18 deg. declination, to the 30th of July, is greater than at the equator. However, in the polar regions, this is much regulated by the quantity of caloric required for the dissolving ice. The mean temperature of the temperate zone, is, at the latter end of April, and the latter end of October: the extremes are on the 21st of January, and the 21st of July. The mean temperature at London is 50·5 deg. But it varies in different years from 48 to 52 deg. It seldom freezes within 35 deg. of the equator, and seldom hails beyond 60 deg.

The difference of the temperature between the surface of the

sea and that of the land is so great, and so various, that no regular scale can be given, which will apply to both. As there is the greatest space of ocean, taken from pole to pole, through the middle of the Atlantic;—this has been fixed on as a standard; and the mean temperature from actual experiments and calculations has been fixed for the equator 84, and for the N pole 31, according to the following table, which is calculated for the northern hemisphere. But this only regards the surface of the sea, at such a distance from the shores as not to be influenced by the temperature of the land; for at a certain elevation above both sea and land is perpetual congelation. The following table shows the mean line of congelation, and its highest limits, above which the vapour must always be congealed.

Latitude.	Mean Temperature at the Surface of the Sea.	Mean limits of Congelation.	Lowest limits of perpetual Congelation.
Equator 0	84 deg.	15577 ft.	28000 ft.
5	83·6	15457	27784
10	82·3	15067	27084
15	80·4	14498	26061
20	77·8	13719	24661
25	74·5	13030	23423
30	70·7	11592	20834
35	66·6	10664	19169
40	62·0	9016	16207
45	57·5	7658	13730
50	52·9	6260	11253
55	48·4	4912	5617
60	44·3	3684	5148
65	40·4	2516	4752
70	37·2	1557	4413
75	34·5	748	4199
80	32·6	120	3861
85	31·4		3631
N. pole 90	31·0		3432

What is commonly understood by climate, is, the temperature peculiar to each country, island, or district; and this is found to depend upon a number of circumstances; and it, therefore, varies in the same latitudes all over the globe. All the continent of America is, with respect to the climate or temperature of the old world, thrown, as it were, 15 or 20 deg. further back or nearer the poles. Newfoundland, the northern parts of Nova

Scotia, and Canada lie under the same parallel as France; yet in those countries, during the winter, the rivers stand cased up with ice of some feet in thickness, and the snow is in proportion. All the birds, at the commencement of that dreary season, desert these inhospitable regions, or they would inevitably perish. Labrador, and the countries round the southern part of Hudson's Bay, are in the same latitude as Great Britain; yet, here "the lakes and standing waters, which are not above ten or twelve feet deep, are frozen to the ground in winter, and the fishes in them all perish. In large lakes and rivers the ice is sometimes broken by imprisoned vapours; and the rocks, trees, joists and rafters of the buildings are burst with a noise not less terrible than the firing of many great guns together. The air is filled with innumerable particles of ice, very sharp, and angular, and plainly perceptible to the naked eye. Bottles of strong beer, brandy, strong brine, spirits of wine set out in the open air for three or four hours freeze to solid ice. The frost is never out of the ground: how deep cannot be certain. They have dug down ten or twelve feet and found the earth hard frozen in the two summer months." The above remarks were made at Churchhill's River, Hudson's Bay—near the same parallel of latitude as the northern coasts of Scotland or the Shetland isles.

But the southern hemisphere displays more frightful scenes, at least during the summer, than the northern. The late Sir J. Banks and Dr. Solander, companions of Captain Cook, made an excursion towards the interior of the island of Terra del Fuego, south latitude 55deg., on the 16th of January, which is the hottest part of summer in those regions corresponding with the middle of our July; when arriving at a hill or mountain of no great height, snow came on suddenly, and two of the party perished with cold, and all narrowly escaped the same fate. Yet, this was in the same latitude in the southern hemisphere, as the northern counties of England; and even the climate of this desolate country is represented as mild in comparison of that of South Georgia, which lies some degrees nearer the equator. Not a tree or shrub is here to be seen; the rocks raise their lofty summits till they are lost in the clouds; and the valleys, during the hottest part of summer, are covered with snow. The north pole may be appoached within 9deg., but a perpetual barrier of ice seems to extend to 15 or 20deg. from the south pole; and innumerable ice islands crowd the seas to a much greater distance. However, though there is a great dis-

parity between the summers of the two hemispheres, it is supposed that the winter of the southern is less inclement than that of the northern.

Also, while the inhabitants under the torrid zone of America are enjoying cool nights and refreshing breezes by day, the Africans are perishing with excess of heat; and through half the temperate zones, the disproportion of temperature between the plains of the northern and southern parts of Africa, and the southern countries of Asia and Europe—are as much hotter than the corresponding latitudes of North and South America, as if these parts of the latter continent were 15 or 20 degrees farther from the equator.

To attempt an explanation of the above phenomena, we have to observe, that though the sun is the grand source of atmospheric heat, yet there are two principal causes which operate to produce very great deviations from any regularity of temperature. The *one* is the heterogeneous and irregular nature of the earth's surface, as hills, plains, woods, cultivated grounds, and burning sands; water, snow, ice. The *other* is electricity, for which see Chap. XVI. s. 12.

The sun's rays only produce heat when they fall upon a suitable medium; they pass through the atmosphere, without in any sensible degree, increasing its temperature. Their effect is in a great measure engulfed in the ocean. In thin sheets of water, where the caloric is not swallowed up by the agitation of the waves, it combines with the water, becoming latent in the vapour and flying off to form clouds and produce rain. Trees, and other vegetables in a living state, absorb the rays of the sun, but retain the caloric for their own use; or if any is emitted, it is chiefly sent off with the vapour. Ice and snow require the caloric of fluidity before they dissolve. In all these cases, therefore, the solar rays will not much increase the atmospheric temperature: though a great deal of caloric must be set at liberty when the vapours condense into rain. But what seems to produce the most effect upon the lowest stratum of air, is, the immediate action of the solar rays upon the soil. The heat of summer does not penetrate deeper than 15 or 18 inches; so that the principal effect must be on the first two or three inches. Here, then, are the rays of a hot summer's day condensed, till an almost burning heat is created, which also heats the contiguous stratum of air.

Any one, casting his eye on a map of the world, will see that

the southern hemisphere is chiefly water, though interspersed with small islands; yet these only serve, or at least the most southerly of them, as nuclei for the ice bergs, so that the whole of the south frigid zone may be considered as a continent of ice; hence the winds from these regions must be intensely cold, since there is no land to charge them with caloric. On this principle the disparity of temperature between North America and the northern parts of Europe and Asia may, perhaps, to a certain degree be accounted for. For, besides the contiguity of the oceans and the inland sea of Hudson's Bay—all this part of America is thickly beset with lakes, that compose a great part of its surface. A powerful cause also exists in the want of cultivation. The leaves of trees are rapid conductors, or it might be said, devourers of heat. America abounds with immeasurable forests of excessively high and close set trees; and in many places beneath them, is a thickly matted underwood. The snow which falls here in winter is entirely screened from the summer's sun; so that, while these regions are bound up in snow throughout the summer, the well cultivated plains, in the same latitudes of Europe, are heated like an oven by the solar rays falling full upon the dry soil.

The West Indian islands are surrounded by deep seas, and are kept comparatively cool by the land and sea breezes. Brazil is variously intersected by mountains, and interspersed with lakes; the same might be observed to a certain degree of all the American part of the torrid zone. Here are also the largest and thickest forests in the world. Though no snow is seen, yet a sunbeam never penetrates through the thick foliage to the earth. While the sandy deserts of Africa are intensely heated, these woods emit nothing but an unwholesome vapour exhaling from the mass of putrefying leaves, the produce of former years. Besides, while the fiery African winds prevail, while the Shumah, blowing in the deserts between Algiers and Tumbuctoo, carries death in every blast, the plains of South America are refreshed with cooling gusts from the frozen tops of the Andes. Peru is always overshadowed with a thin grey cloud, the vapour from the Pacific Ocean passing to the summits of the mountains, which protects its plains from the scorching heat of a vertical sun; and the same may, to a certain degree, be observed of Chili.

We do not want proofs in the old world, that very high mountains are capable of producing considerable effects on the

atmospheric temperature. Near the elevated mountains of Thibet, at Chamnanning N. latitude 31 deg. 39 min., the thermometer, in the winter of 1774, stood, even in a room, as low as 29 deg. below freezing point. In the middle of April, the standing waters were all frozen over, and heavy showers of snow frequently fell. It does not appear to be a solitary instance peculiar to that year. Yet this place is farther south than the northern burning climate of Africa; the mouth of the Nile; and some of the scorching deserts of Arabia.

While exhausting the receiver of an air pump, no sooner does rarefaction commence than excessive cold always appears. Hence, was there a burning heat on the summits of very high mountains, so cold is the air by its great rerefaction, that the heat would be dissipated all around without producing any sensible effect. The higher the hill, therefore, the greater the cold; because the air is so much the rarer; and the deeper the valleys the greater the heat; the air being proportionately denser. But the heat on a plane can only be dispersed upwards, while that on the summits of a hill can disperse on all sides or down the declivity of the hill. The one has therefore nearly a globe to radiate in; the other only a hemisphere; and in a valley, or at the foot of a hill, the heated air has much less than a hemisphere to disperse in: consequently, low situations must have a much higher atmospheric temperature, than those that are elevated.

CHAP. VII.

The Atmosphere and some of its Uses.

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1. The Composition of the Atmosphere. 2. Atmospheric Pressure, the Barometer, Hygrometer and Air Pump. 3. Various Uses of Atmospheric Pressure. 4. Elasticity of the Air. 5. Sound or Acoustics. 6. Musical Strings. 7. The Human Ear. 8. Clouds. 9. The Quantity and Distribution of Rain.

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1. COMPOSITION OF THE ATMOSPHERE.

Atmospheric air consists of two gases, viz. oxygen and nitrogen, mechanically blended together in the proportion of 21 parts oxygen to 79 nitrogen, if taken by measure; but if by weight, the proportions are about 23¼ of the former, to 76¾ of the latter. Besides these two gases, there is always found some carbonic acid gas mixed with the atmospheric air, generally in the proportion of one part in 1000; and certain other lighter gases, in small and varying proportions, as hydrogen and carburetted hydrogen, with a continually varying quantity, but generally in the proportion of from one-sixtieth to a hundreth part, of water in the state of invisible elastic vapour. Several other invisibly small substances are also continually floating in the atmosphere, being the effluvia and exhalations arising from the various decompositions, that are unceasingly going on in the animal, vegetable, and mineral kingdoms.

All these heterogeneous substances compose the atmosphere; and as they vary from each other in density, there is, notwithstanding the nature of gases to act as vacua to each other, a tendency to dispose themselves in the ærial regions according to their respective specific gravities. If this tendency was not counteracted by the winds, we should have the carbonic acid

gas forming a layer round the earth, which would cover the waters and a considerable space of the valleys; and as this is the choke-damp, which has so frequently proved fatal to the human race in mines, wells, and cellars, a great part of the lower grounds would be uninhabitable. Upon the carbonic acid gas we should have a thick layer of oxygen gas or vital air. This would be the atmosphere of the more elevated grounds, and would extend above the tops of the highest mountains. Though this is the air which supports life; yet, it is mixed with between four and five times its quantity of an air or gas that has a contrary effect, viz. nitrogen or azote the depriver of life; and our bodies are constituted to this proportion;—consequently, were we to breathe oxygen gas alone, it would be too strong for us, we should live four or five times too fast, and in a short time wear out the vital machinery; and, therefore, the more elevated plains, the hills and mountains also would be uninhabitable. Next the oxygen gas would be the nitrogen. Above that, vapour or aqueous particles; then the carburetted hydrogen gas; and at the top of all, the pure hydogen gas, which is the lightest of all ponderable substances: being thirteen times lighter than atmospheric air. Besides these pincipal layers, there would be small intervening strata of all the different æriforms and effluvia that ascend from the earth.—From this we may see the great importance of the winds, which are nothing more than this vast mass put in motion by various causes; and which blend the whole and keep it in a fit state for all the purposes the atmosphere was designed to answer.

However it is owing to the agitation of the whole, and its being so regularly blended, that some of the ingredients are raised or suspended in it. For a layer of pure aqueous vapour, such as we have supposed, could not exist at the temperature of the air; and would, therefore, be immediately condensed by the cold, and fall down in mist or be precipitated in rain.

It is owing to the winds, that the atmospheric air is found to consist of the same ingredients in all parts of the world. Carbonic acid gas, though considerably heavier than any of the other materials, has being found on the top of Mont Blanc, the highest mountain in Europe; and æronauts have detected it at their greatest elevations. But perhaps it exists in small quantities in these upper regions; for the followers of the unfortunate La Perouse could not detect it on the Peak of Teneriffe. The quantity of aqueous particles varies much, there being the most

in islands, and maritime situations; less in the midst of large continents; and winds, blowing from the interior of Africa, are sometimes found so utterly destitute of moisture, that the furniture in the houses on the coasts of Barbary is warped and rent with a thousand chinks. The skin, also, on the lips and nostrils of the inhabitants, becomes so parched and shrivelled as to peal off. It is this thirsty wind that so exhausts the Mediterranean of its waters.

In some parts of the world, calms have continued so long, that the air became corrupt and pestilential. This might be partly owing to the morbid state of the earth with respect to the developement of its electric principle; but as much, perhaps, to the tendency of the atmosphere to pass into the stratified state, when the carbonic acid gas, subsiding to the earth's surface, made the air unfit to breathe. In pits, cellars, and other places not ventilated, this gas always lurks; and is principally the cause of the air being unwholesome in large towns.

2. ATMOSPHERIC PRESSURE, BAROMETER, HYGROMETER, AND AIR PUMP.

It was stated, Chap. V. s. 3. that the limits of the atmosphere cannot be ascertained; but that, at an elevation of 45 miles, it is so thin as not to refract the sun's rays; and that its pressure is equal to 15lbs. upon every square inch of the earth's surface. But as the quantity of vapour, which the atmosphere contains, varies at different times; and as these vapours are by the electric principles often collected into extensive masses, when they are visible as clouds, and the vapour itself being one-sixth lighter than atmospheric air;—the pressure will, therefore, be less upon the earth's surface immediately beneath these collected vapours, than where the air is clear.

Another circumstance also tends to cause variations in the pressure of the atmosphere on particular parts of the earth's surface. This is the winds. Should we take a long trough with a partition in the middle, and fill one end exactly to the brim with water; on taking out the partition, the water will seek its level and fill the whole half full. But in doing so, the surface will fall in that which was at first the full half, near the place of the partition, much lower than where it will stand when it has found its level; consequently, while the stream is running the pressure on the bottom will be less over that part. This

diminution of pressure will begin to take place all along the full end, even before the water can be said to be so much moved as to form a stream. Now as portions of the atmosphere are frequently put in motion, viz. by the collected vapours being precipitated in rain, and the surrounding air rushing in to take their place, we may easily conceive how the pressure may vary at the commencement of, and during a wind, though the rain falling be at such a distance that no clouds are visible.

A very useful instrument called the *barometer*, constructed on the principles of the common pump, is made to indicate the variation of this pressure. It consists of a small glass tube filled with quicksilver; see Fig. 28. The tube is closed at one end, and bent at the other, which is open. It is about 34 or 36 in. long from the closed end to the bend; and when the metal is put into it, it is boiled to expel the particles of air, that may be in it, and so might prove prejudicial to it movements. Being filled to the bend, it is turned with the close end upwards; the open end being also upwards by reason of the bend. The mercury now sinks to the measure of the atmospheric pressure; and a vacuum being formed in the upper part of the tube *a b*, and the atmosphere pressing upon the fluid metal in the orifice of the lower part *c*;—it is thus suspended as the water in the common pump.

Water will rise from 30 to 35 feet high, according to the existing pressure; but as mercury has a specific gravity of almost 14 times that of water, a column of this metal of from 27 to 31 in. will be nearly equal to the above column of water; consequently the mercury ranges in the barometer between 27 and 31 in.; which space, to complete the instrument, is graduated: each inch being divided into ten parts.

Sometimes the tube is straight, and its orifice is merely suspended in a small trough of mercury; and sometimes the orifice *c* is made wider than the rest, and a piece of card or cork swims upon the metal, having a thread fastened to it with a small weight *d* at the other end. The thread coils round a wheel attached to an index. When the atmospheric pressure increases, more of the mercury is raised up into the longer leg of the tube; and, of course, the float *e* descends. Should the pressure be diminished, the mercury rises towards the orifice; and the float ascends; and these communicate corresponding motions to the wheel and index.

The barometer is also called the *weather glass;* because when

the atmospheric pressure is diminished by the accumulation of vapour over any part of the earth's surface, rain is almost sure to follow; and when it begins to fall by the second cause, wind may be expected. When the atmosphere returns to a settled state, that is, when the vapour is precipitated, and the vacuum is filled up by the surrounding air rushing in as wind, the mercury rises, and we look for calm and settled weather: see Chap. XVI. s. 11.

The *hygrometer* is another instrument for prognosticating rain, but on a different principle from the barometer. It is made of slips of whalebone, strings of catgut, the beard of the wild oat, or any substance that readily attracts moisture. Should the air be in such a state as not to suspend the aqueous particles, the substances become relaxed and damp, and rain may be expected; but when it buoys them up, the material forming the hygrometer remains dry with an increase of tension. Should a string of catgut be coiled round a very delicate wheel with an index like that of Fig. 28, one end fastened to the wheel and the other to a pin at a yard distance; by its contractions and relaxations, it will move the wheel, and the index will point out the state of the air.

The *air pump* is an instrument for making experiments on the mechanical properties of the atmosphere. It consists of a large glass vessel in the shape of a bee-hive, called the receiver, which is placed upon a brass plate, that has a hole in the middle; a piece of wet leather, called a collar, being inserted for the better exclusion of the air. A barrel is fixed to the hole in the brass plate, in which is a piston and a valve, that works in the manner of a common pump. Sometimes there are two pistons and valves; and they are so contrived as to work with a handle or winch, which being turned, the air is pumped out from the receiver.

By this apparatus, it has been ascertained, that the atmosphere presses upon each square inch of the earth's surface with a force equal to 15lbs.; that it presses equally in all directions; that it is elastic, having a spring equal to the force that compresses it; that on account of this elasticity, it varies in density at all altitudes; and that it is rendered more elastic by heat. It has also been ascertained that a cubic inch of air in vacuo, will raise the barometer nearly as high as the whole atmosphere. A half blown bladder put into the receiver, will, while the receiver is exhausting, expand and finally burst. A similar effect is

produced in all bodies containing imprisoned air. In the exhausted receiver the smoke of a candle, having no air to rise in, will fall to the bottom; a pistol fired in it will make no report; no lamp or candle will burn, and no animal can live in it.

3. VARIOUS USES OF ATMOSPHERIC PRESSURE.

As the atmosphere presses equally in all directions, whether upwards or laterally by its spring, or downwards by its weight; every square inch, therefore, of the surface of a man's body must be pressed with a force equal to 15lbs.; so that the collective pressure against all parts of his body will amount to 12 or 15 tons. It has been sometimes stated that he bears all this weight upon him, but it is not so; for he is as much buoyed up by it, as he is pressed down; and he may, therefore, be said rather to swim in it, than otherwise. By this pressure it is, that the skin is made to fit so tightly to the body, and shew all the shape of the muscles; instead of stretching smoothly across the cavities, or hanging loosely around the whole like a sack. Were a man placed in an exhausted receiver, the air confined in his body, and the vapour that would be immediately generated by the vital heat, would so expand as to rend the fleshy fibres and burst the skin. It is related of Count Zambeccari and his companions, that they ascended so high in an air balloon that their hands and feet swelled, till it was afterwards necessary for the surgeon to make incisions in the skin. The same has frequently taken place, but in a less degree, in persons ascending to the tops of very high mountains: the atmospheric pressure not counterbalancing the fluids of the body.

As this pressure of the atmosphere is almost continually varying, so as to cause the barometer at times to rise or fall three inches, which is about one-tenth of its height; so the pressure against the body will also vary; and therefore persons of delicate constitutions need not wonder at their feeling great uneasiness previously to rain or a very high wind, when they are told, that the pressure, which braces their bodies, will sometimes diminish almost a ton in the space of a few hours; and in a man of the largest size may even vary a ton and a half. However, this is not the sole cause of such uneasiness: see Chap. XX. s. 7.

Though the atmosphere is an auxiliary cause of evaporation, by holding the vapour in suspension, and taking it away from

the surface of the earth as fast as it is generated; yet, by its pressure it greatly regulates the process. For, though water on a plain will not boil till it attains a temperature of 212deg. yet, on the top of Mont Blanc it was found to boil at 187deg.; and all fluids are said to boil in *vacuo*, that is, in an exhausted receiver, at a lower temperature by 145deg. than under the pressure of the atmosphere. Water, therefore, boils at 67deg.; so that, were it not for this pressure, in one of our hot summer's days, when the thermometer ranges, perhaps, between 70 and 80deg.—the whole of the water on the earth's surface would be converted into steam; and on most occasions evaporation would take place as soon as ice should be dissolved; so that we should have only ice and steam, and no water. It is observed that when spirits and ether are exposed on the tops of high mountains, they quickly lose, by evaporation, all the particles on which their value depends.

The *pulse-glass* will shew how readily a liquid boils in *vacuo*. It is a small glass tube with a bulb at each end, containing a little spirits of wine, but exhausted of the air; and hermetically sealed. Should this instrument be held in a sloping direction, the liquid, by the mere heat of the hand, will soon begin to boil; and the vapour, rising to the cold bulb at the other end, is immediately condensed: in this manner would the whole of the liquid pass from one bulb to the other.

Though the receiver of the air pump is merely placed loosely upon the plate; yet, when the air is exhausted, being pressed to the plate with the force of 15lbs. to every square inch of the external surface, it requires a great force to remove it. When two hollow hemispheres are placed in contact with each other and exhausted, they cohere very firmly; they are called the Magdeburg hemispheres, because in that city, a pair was made sufficiently large to withstand the draught of the emperor's six coach horses. A great many operations are carried on by the pressure of the atmosphere; among which is that of a child sucking the breast: he makes a vacuum in his mouth, and the atmosphere presses the milk into it. The limpit exhausts the air from its shell, which fits close to the rock, and the atmosphere presses it so tight that with great difficulty we remove it; and on this principle it is that the boy lifts a stone with his leathern sucker. The upward pressure is often exhibited to children, by laying a card or a piece of writing paper over a tumbler glass filled with water; then, pressing the card or the

paper with the flat of the hand, the glass may be turned upside down; and though the paper be no longer held, may be thus carried about without spilling a drop.

4. ELASTICITY OF THE AIR.

THE weight of a column of air one foot in height, is equal to one twenty-eight thousandth part of the atmospheric pressure; consequently, was the air of uniform density, the elevation of the atmosphere would be only 18,000 feet, or a little more than 5¼ miles. If this were the case, it would be easy to measure an elevation by the variation of pressure, since at the elevation of 2 miles there would be a pressure of only 17·540 feet;—but as the elasticity of the air at the earth's surface is such as to be nearly equal to its downward pressure—of course, the upper regions, which have little or no pressure, will consist of air almost infinitely expanded: hence, it is calculated, that at an elevation of 4000 miles, a cubic inch taken at the earth's surface would expand so as to fill the orbit of Saturn; and that in a mine at the depth of 42 miles below the earth's surface, it would be as dense as quicksilver. Considering the pressure at the earth's surface, or 28,000 feet the standard, it has been deduced, that at an elevation of 18,000 feet the density will be about a half; at 36.000, a fourth; and at 54,000 feet, one eighth. However, such a multitude of circumstances tend to cause variation in the atmospheric density and pressure, that no exact or satisfactory scale to suit all elevations has yet been given.

In ascertaining elevations by the barometer, it is found that the mercury falls one-tenth of an inch for an elevation of 100 feet *near* the earth's surface. On the top of Snowdon it stands generally at 3 inches lower than on the plain;—the elevation of the mountain being 3,720 feet. The difference of atmospheric density, as existing on the top of a mountain and on a plain, in a valley or at the level of the sea, is easily ascertainable. Take a glass tube of uniform diameter, closed at one end, the other or open end being immersed in water or mercury;—then, marking where the water or mercury stands on the mountain, and also how high it is forced into the tube when on a plain, both the difference of density and the altitude of the mountain, according to the above scale, may be ascertained. Thus: should the mercury on the plain occupy half the tube,—then, the density on the mountain is half that on the plain, and its height must be 18,000 feet.

Bodies that are of less specific gravity than atmospheric air, under that pressure which it has at the earth's surface, will swim in it; and ascend till they arrive at a place where an equal bulk of it is of the same specific gravity with themselves, and there remain stationary. This is the foundation of the science called *aerostation*.

The *air balloon*. Hydrogen gas is 13 times lighter than atmospheric air; therefore, should a quantity of this gas be collected into a bag made of very slender materials, such as varnished silk,—it will, as cork rises from the bottom to the surface of a vessel of water, ascend to the upper regions of the atmosphere. As the bag is filled under the atmospheric pressure, of course, it will dilate as it gains the aerial regions: being there acted on by a less pressure. If therefore we wish it to ascend to the greatest possible height, it should be made large and capable of holding much more gas than is put into it at the earth's surface; so that, as it is elevated, the gas may have room to expand. But in this case the specific gravity, not only of the gas but of the materials which confine it, must be taken into consideration. Allow the body of gas confined in a large balloon to be 13 times lighter than atmospheric air at the earth's surface, and suppose it to be nearly full; then, making no deduction for the weight of the materials, it might perhaps rise 10 or 12 miles. But besides the glazed silk, the bag is confined in a net, which serves as a frame work for the whole; and to which a car or boat is suspended, that frequently contains two persons with sundry articles. All these prevent the gas from expanding, and considerbly increase the specific gravity of the whole; so that, instead of rising 10 or 12 miles, it will not rise above 2 or 3. However, this is found high enough for any animal to ascend; for the difficulty of breathing at this elevation is very great; the vital air being too thin for the supply of life.

In June, 1804, two gentlemen ascended in a balloon from Petersburg, and took three live pigeons with them, which they liberated at different altitudes. The birds seemed terrified, and apparently not without reason. For, on turning off the first, its wings appeared to be nearly useless for a great way in its descent. The second struggled hard, but in vain, to regain the car; and the third, which was thrown out at the greatest height, fell like a stone downwards; so that it is supposed that it would be dead before it arrived at the earth. Birds respire more, in proportion to their size, than men; consequently they

would be more exhausted than their companions, and therefore we need not wonder at their fear and unwillingness to quit the car: being both out of breath, and not having air sufficiently dense to afford hold for their wings.

That the balloon may not rise too rapidly at first, the aeronaut takes with him a few bags of sand, and throws them out when he would increase his elevation. When he wishes to descend, by cords attached to a valve at the upper part of the bag, he can permit any quantity of gas to escape so as to regulate his descent. Cold is a great inconvenience to aeronauts; for at an elevation of little more than a mile and a half, even in summer, the temperature over England is at the freezing point; and at double the height, as stated Chap. VI. s. 12, is perpetual congelation even under the torrid zone.

Atmospheric air is generally said to be compressible into 128 times less space than it usually occupies at the earth's surface; and were the force increased with instruments sufficiently strong, it is not known to what degree of density it might be compressed: some late experiments seem to prove that it may be condensed till it assumes the form of a permanent fluid. At a density of 128, its spring is always nearly equal to the force which compresses it; so that, however long it may be kept in this confined state, it is always ready to recover its former bounds. But when atmospheric air is compressed, it invariably emits both light and heat; therefore, it will lose a little elasticity on account of this loss of caloric; and, for the same reason when it recovers its equilibrium, it produces a very sensible degree of cold. At the mines of Chemnitz, in Hungary, is a very curious machine called the fountain of Hiero; wherein air is compressed with a column of water 260 feet high—which is about eight times the atmospheric pressure. Whenever a little of this air is permitted to escape, the moisture contained in it congeals and falls down in snow, or adheres in icicles to the stop cock. On this principle may the extreme cold, which prevails in the upper regions of the atmosphere, in some measure be accounted for.

The *air gun* is an instrument constructed on this elastic principle of atmospheric air. The air is compressed into a small hollow globe, by an instrument called a condenser, which consists of a barrel, a piston, and a valve. One of these globes, wherein the air is condensed, is screwed on to the lower end of the barrel of a fowling-piece made for the purpose; and the ball

being properly disposed, on pulling the trigger, the air escapes; and by its elastic spring, propels the ball with a velocity nearly equal to that given by gunpowder.

The elasticity of the air may be easily proved by placing a cork or a bit of paper upon water, and inverting a common tumbler glass over it —when, should the glass be pressed down, the air inside will prevent the water from rising above a certain height, as will be shewn by the cork or paper swimming on the surface. The *diving-bell* is an apparatus of this kind, only on a larger scale. It is shaped like the glass, open at the bottom, and suspended like a common bell. Inside are seats for one or more persons; and weights are disposed around the bottom to balance it, and cause it to sink. Being thus prepared, it is let down into the water, with the divers in it, sitting in the upper part wherein the air is compressed. At 34 feet beneath the surface of the water, the density of the air inside the bell is doubled; and at 68 feet, it is trebled; which compression occasions an uneasy sensation in the ear, by the great pressure of the air against the membranum tympani. But the greatest inconvenience arises from the oxygen gas, or vital air, in so small a space being very soon exhausted. To remedy this, they contrive to let down as needed, barrels of fresh air, which are emptied by the divers into the bell; and a stop cock at the top of the bell permits the effete or contaminated air to escape. These barrels are let down in the same manner as the bell, that is, the bungs are open; but, being at the under side, it answers the same purpose as if they were carefully closed; and thus saves a great deal of trouble. A forcing pump is sometimes affixed for the supply of air. Inserted in the upper part of the bell, is a square of glass for the sake of light. Candles have been used for this purpose; but a small candle is found to consume as much air as one person, and to contaminate the rest much more. By this apparatus, ships may be unloaded at the bottom of the sea; the heavy materials being drawn up with ropes, which the divers fasten to them.

The great difficulty and danger attending diving bells arise from obtaining the fresh air. Two young men descended in one to visit a wreck in the Bay of Dublin. They were to ring a bell for the cask intended to supply them with fresh air; but, by the contraction to which ropes are liable on being wetted, the bell turned round in its descent, and thus entangled the cords communicating with the bell. The assistants stationed

above waited too long for the signal; and on drawing them up, found them both dead. They were not drowned, but died the death of the unfortunate people in the hole of Calcutta, namely, for want of vital air.

The *forcing pump*, Fig. 29, is another pneumatical instrument depending on the elasticity of the air. By the common pump, water can only be raised from 30 to 35 feet; but by the addition of the forcing apparatus, the height is unlimited. It consists of an upright tube like the common pump; but the piston or plunger contains no valve. A little above the valve B, which is fixed in the tube, is another side valve, and a tube that leads to a strong iron vessel. When the piston rises, the water ascends into the chamber between the piston and the lower valve, where it is secured by the valve; which, opening upwards, is, when the chamber is filled, pressed down by the water. The piston then descends, and forces the water through the side tube into the air vessel D; and its return is in like manner prevented by the valve C. Into the top of this air vessel is fixed a small tube that descends inside to *e*, or almost to the bottom of the vessel; so that its orifice is beneath the surface of the water; and the air is compressed into the upper part of the vessel with the force with which the piston descends. The elastic spring of the air pressing upon the surface of the water, forces it up through the pipe in a constant and regular stream.

The *fire engine*, and the engine for watering gardens, are constructed on the same principle; as is also the artificial fountain. This last instrument, chiefly used for the amusement of children, consists merely of a bulbous air vessel, into which the water is put before the air is compressed. The compression is made by a condenser. The pipe is furnished with a stop-cock; which, when opened, permits the water to escape in a fine stream, that descends in a beautiful manner like a shower of rain.

5. SOUND OR ACOUSTICS.

Among the numberless advantages derived from the elasticity of air, is that of sound; which is nothing more than the air put in motion by sudden and violent jerks or pressures. These give rise to propulsions or vibrations, that move somewhat in the same manner as the undulations seen in water when we throw a stone into it. But in air they are much more pungent and decisive, on account of the great velocity with which they move.

The sensation of sound is caused by these vibrations extending themselves to the air that occupies the internal parts of the ear, and giving motion to the instruments therein placed, which are most suriously contrived, so as to produce certain effects on the auditory nerves. During winds the air moves in streams, or a portion of the atmosphere changes its place; in sound it moves without changing place. The velocity of the swiftest wind, in this quarter of the globe, seldom exceeds 50 or 60 miles per hour; while the propulsions that produce sound move at the rate of 778¼ miles. Was the quantity of air, which is put in motion during a wind, to move with the velocity of sound, not to mention the general distruction of nature, our ears would be for ever disabled by the blast. A cannon ball moves nearly with the same velocity as sound; hence engineers and others have frequently lost their hearing, by their heads coming in contact with the air struck by the firing of large guns, or the passage of balls:—the extent of the vibration at the focus being so much greater than it is at a distance.

That sound depends upon the air, may be proved by a bell suspended in the exhausted receiver of an air-pump; when, however struck, it will emit no sound. Aeronauts, when at great elevations, can hardly hear themselves speak; and a pistol fired in these upper regions, makes very little report. It is chiefly, therefore, to the density of the atmosphere that we owe the origin of sound. However the atmosphere is not the sole medium of sound. It may be propagated in water, as may be proved by ringing a bell in it, which will emit a sound one-fourth more loud and shrill than when rung in air. Fish, as is very well known, have the sense of hearing very acutely at the greatest depths. Sound is also capable of being transmitted through solid bodies; and that to a certain degree, with greater velocity than through air.

The human voice is propagated by the expulsion of air from the lungs. At the top of the trachea or wind-pipe is the larynx, consisting of four or five cartilaginous and muscular rings, by which we can adjust the orifice called the glottis to any width. The diameter of this orifice at its utmost stretch is about one-tenth of an inch, and the human voice is capable of sixty variations; therefore, each alteration in the adjustment of this orifice or of its diameter cannot exceed a six-hundredth part of an inch. On the strength of the muscles of the larynx, or their more or less perfect conformation depends the peculiarities of the voice, as to strength, sweetness or otherwise.

The anterior and larger part of the larynx is composed of two cartilages; one of which is shaped like a buckler, and the other resembles a ring.—The former by its convexity forms the eminence on the front of the throat called Adam's apple. Together they compose a muscular box in which is enclosed the glottis. In speaking and singing this organ or box moves up and down, as may be distinctly perceived by the external application of the finger. For producing an acute note or a shrill tone, it is drawn upwards and more forward; and to assist the contraction of the muscles, the head is reclined backwards, so that the orifice is much narrowed. But for producing the lowest bass notes or deep tones the head is brought forward to relax the muscles, when the organ descends; and the orifice is widened to its greatest stretch. The lowering or raising of the organ is an inch for every octave, and the strength of the voice principally depends on its size—for it is very small in females and those who have a weak voice.

But though the voice originates at the glottis, it is in the mouth where the power of speech is situated. The tongue, with the assistance of the teeth, lips, and all the parts that compose the mouth, modulates the sound after it has been propagated, apportions it out in lengths, articulates them, and gives them different intonations; a certain number of which, arranged according to certain laws, being the sign of some idea, we call a word.

Wind instruments with stops may not improperly be denominated artificial voices. The orifice at which the wind enters is the glottis; and the stops, though not capable of giving articulation, can produce modulations similar to those of the human voice. All bodies, that are elastic, when struck will emit sound; for, it is evident, that when a body is sounding it is in a vibrating state; and its vibrations impart corresponding impulses to the air. Wind instruments are struck by the air; and they, in return, imprint other motions on the air. That portion of air escaping from the different holes or stops, gives the different modulations by altering the vibration of the instrument; and by their being disposed at certain distances, they produce the same effect as when stringed instruments are struck.

It is, perhaps, on the same principle that homogeneous solid bodies conduct or transmit sound. Thus a watch placed at one end of a long piece of timber, or at the end of several pieces

conjoined, may be distinctly heard by placing the ear at the other end; the whole of the timber being in unison, transmits the sound or continues the vibration from one end to the other; and that in a less space of time than it could be transmitted through the air. Sound is transmitted a long way on the surface of water, providing no stream intervenes; and footsteps may be heard at a great distance in a still night, by placing the ear upon the ground. This is much practised among savage nations, especially when at war with each other; and it is said that the reports of cannon fired at Toulon may be heard, by this means, at Monoco, though the distance is 75 miles.

The distance to which sound may be heard through the air, depends on a variety of circumstances. In calm, serene weather, when every thing is quiet, and the barometer is high, sound is much stronger, and is heard from a much greater distance, than under the opposite circumstances. It is heard farther over a smooth surface, and still water, than over a rough, uneven surface, beset with trees and other objects, or over agitated water. Under favourable circumstances, St. Paul's clock has been heard to Windsor. An instance is related of the human voice having been heard ten miles. An ordinary musket cannot be heard above seven or eight miles; but the discharging of several, not simultaneously but following each other very closely, may be heard from a much greater distance. It has been said, that in the Dutch war of 1672, the reports of cannons were heard at the distance of more than 200 miles.

Sound owes a great deal of its strength to reflecting surfaces; for it moves from the focus or place where it is generated in a globular manner, that is, spreading on all sides; and the radii are always equal, since the gentlest whisper is found to move with the same velocity as the loudest report of a cannon. Should the focus be at the earth's surface, the sound therefore will have only a hemisphere to move in; and will be of double the intensity that it would be of if the focus were at a considerable elevation in the atmosphere.

Sound is capable of being reflected like light and heat, and the reflected wave is called an *echo*. As the angle of reflection is equal to the angle of incidence, echoes will not often be heard; for a person can only hear the echo of his own voice, when the reflecting surface, be it the wall of a house side, a rock, or hill, is at right angles with a line from his mouth to that surface. In this case, he may pronounce the syllables 1, 2, 3, 4, 5, 6, so

as the next word 7, would occupy two seconds; and standing at the distance of 1142 feet, he will hear them distinctly repeated by the echo, which will seem to begin as he ceases. Should a person stand half way between him and the reflecting surface, but in the line of coincidence, he will hear each syllable twice; that is, as it passses to the reflecting surface and as it returns. But should the reflecting surface be oblique to the line of incidence, then, the echo will be only heard by a person standing at the angle of reflection; and not by the person himself. Hence a person speaking in a narrow passage, among rocks, in a dell, or in the mouth of a cave (from this circumstance called a repeating cave), will sometimes hear many echoes; and sometimes a re-echo, or the sound a second time reflected; and at other times, he, though in company, will hear a sound which no one else hears: he alone being at the angle of reflection.

On the above principle, sounds are capable of being condensed, or of being collected into a focus. The larynx and glottis form the place where the human voice is propagated; but it is condensed by the mouth; and the speaking trumpet, which may be considered as an elongation of the mouth, still farther condenses it. The common speaking trumpet, is merely a tube enlarging from the end applied to the mouth to the other end. This perhaps is the best shape for a trumpet that is to comprehend a field within the sweep of the sound. But a speaking trumpet may be so constructed, that the sound shall be collected into a line; so that, if two persons are standing together, one only shall hear it. The tube of this instrument, according to Walker, is uniform from the mouth end, till it comes nearly to the other end; when it suddenly enlarges, or bends backwards almost in the manner of a French-horn, but more abruptly. However this instrument can only be used where it can be fixed; and it is that which enables juggling itinerants to make their figures speak.

The same form would answer better for the *hearing* trumpet, because the line can be directed into the orifice of the ear; though they are very seldom made in this shape, the conical being that which mostly prevails. The principle on which hearing trumpets act is this:—their wide end being directed to the place whence the sound issues, collects and condenses the vibrations of the air and transmits them into the ear. In short, if we examine the human ear, we shall find the hearing trumpet but a clumsy imitation of it. It may, therefore, be considered

as an elongation of the external ear, and man frequently performs its office by the application of his hand. We also see all animals in the act of listening, turn the orifice of the ear towards the sound,—stretching it open to collect as wide a portion of the waves as possible.

The well known whispering gallery in the dome of St. Paul's is the inside of a hemisphere, so that if the mouth be placed at one side, and the ear diametrically opposite on the other, the gentlest whisper may be heard as distinctly as if the mouth and the ear were both together. For at the place where the ear is situated are all the waves collected into a focus;—it being the place where, according to mathematical rules, all the lines of reflection will meet from the places where the lines of incidence impinge upon all parts of the hemispherical cupola, as well as the wave that travels diametrically across to the ear. But should the ear not be diametrically opposite the mouth, the words will be heard doubly or confusedly; since the waves coming directly or along the shortest arcs will arrive sooner at the ear, than those that make the circuit of the longest.

All sound whether it be a gentle whisper or the dreadful report of the cannon, travels with the same velocity, viz. 1142 feet per second, or about 13 miles per minute: but when its motion is against the wind it is slower, and when with the wind it is quicker—in the former case the velocity of the wind must be added, and in the latter it must be subtracted. The transmission of sound has therefore been applied to ascertain the distance of objects. But this can only be done when we can see the act that produces the sound, as in the case of firing a gun we see the flash. Light, from its quick transmission is considered as instantaneous in its passage; and, therefore, we suppose the flash to be seen at the same instant in both places. Suppose then a gun be fired from a ship in distress at sea, the sound will not be heard for some time after the flash is seen. Should we count the intervening seconds by a watch and multiply them by 1142, the number of feet that sound moves in a second, it will give the distance of the ship. Or, seeing a cannon fired at a certain place, at a known distance, whence the wind blows direct, then the time in which the sound arrives subtracted from the time in which it would arrive in a calm, will shew the velocity of the wind.

The time occupied in the transmission of sound accounts for the continued rumbling noise of thunder. For though a peal

continue 20 seconds, it is but one clap as instantaneous as the crack of a pistol. Suppose a flash of lightning extend four miles along a thunder cloud. This flash, as may be seen by the eye, is simultaneous from end to end; and is, by the sudden vibration it gives to the air, the cause of the sound we call *thunder*. A person, stationed directly under one end of the flash, will see the whole chain exactly at the same instant. Suppose the cloud 380 yards high, he will hear the report or commencement of the thunder just one second after he has seen the flash. But as the other end of the report is four miles from him, it will be more than 18 seconds before the sound reach his ear; yet, during the interval the vibrations from the intervening part have been entering his ear, preserving the continuity of sound or the rolling of thunder. Should he be placed about half way between the two ends, he will hear the thunder peal, as it were, separate into two branches—the sound coming from each side at the same time; but it will be of only half the duration.

6. MUSICAL STRINGS.

It is found that if a string be stretched between two pins, and then be struck or pulled to one side it will move as far to the other side, and then nearly as far back again; and thus vibrate for a considerable time:—each vibration diminishing till they finally cease—though the time occupied in each vibration from beginning to end is exactly the same. Two strings in every respect the same, will produce exactly the same tone, and are said to be in *unison*. A string half the length of another will vibrate in half the time, or make two vibrations for the other one,—each second vibration of the shorter one commencing with each vibration of the longer one. A string two thirds the length of the long string will vibrate three times to its twice. Should we suppose the long string to consist of 120 parts, and to vibrate 60 times in a second, then we may have seven divisions of it, with their according vibrations; and the number of times which each one vibrates in a second, as in the following table.

Names of Strings.	Divisions of the Long String.	According Vibrations.	Vibrations in a Second.
First	1 or 120		60
Minor Third	$\frac{5}{6}$ - 100	6 · 5	72
Major Third	$\frac{4}{5}$ - 96	5 · 4	75
Fourth	$\frac{3}{4}$ - 90	4 · 3	80
Fifth	$\frac{2}{3}$ - 80	3 · 2	90
Minor Sixth	$\frac{5}{8}$ - 75	8 · 5	96
Major Sixth	$\frac{3}{5}$ - 72	5 · 3	100
Octave	$\frac{1}{2}$ - 60	2 · 1	120

These strings, when struck, will produce different sounds; but the vibrations of each will accord or commence together at the above stated intervals with the original long string; and they are, therefore, said to form a concordance or to harmonize. When the strings have not those proportions, and consequently not these periodical concordances, they form discords by the vibrations continually intercepting each other, and thus jarring or checking each others momentum.

The above proportions constitute the diatonic scale, and are the foundation of all music;—producing the greatest number of recurring vibrations or concords that can be had at the least intervals; and, with the addition of five intervening strings that produce half tones, each one being a sharp to the one below and a flat to the one above, constitute the musical alphabet. All the strings together form one octave. But the same divisions may be repeated on the short string or 60, when its octave will be 30; and this may be again divided; as also its octave. Some instruments contain 10 octaves, rising one above another; yet, constructed on a regular scale, so as to preserve the proportions. The piano generally has 5, but sometimes 7 octaves.

The strings are not thus exactly measured in all instruments; because the least difference either in the materials of which strings are made, their thickness or tension, which is continually varying with the weather, makes a difference in the tone. They are therefore fixed according to the sound itself, as determined by the accuracy of the ear;—which is called *tuning* them. The construction of most instruments must consequently depend on the ear; for in many wind instruments, in musical glasses, and even in a great many stringed instruments, no actual proportions can be applied; and the only means we have of producing the above sets of harmonies or octaves, is, by altering and adjusting the instrument or tension of the string till the right tone is produced. In the violin the lengths of the strings are varied by the disposition of the fingers; and in the flute the octaves are chiefly produced by the manner of blowing.

The vibration of strings is on the same principle as that of pendulums:—each string being considered as two pendulums joined together at the points of oscillation, and as describing very small arcs. Now as pendulums of the same length oscillate in the same time, whether the arcs which they describe be great or small, so the vibration of equal strings will be performed in the same time:—hence, though one string be violently struck so as to produce a loud sound, and another in unison, so gently as

scarcely to produce any sound; yet, as each vibration is performed in the same time, the tones will have the same pitch, or, the strings will be in tune.

If a pendulum of a certain length vibrate in a certain time, then one that is one-fourth the length will vibrate in half that time:—the time of vibration being as the square root of the length. But to produce the same effect in the string or double pendulum, we must work with half the length,—or as the pendulum decreases in the ratio of 1—4, the whole string must decrease as 1—2. Now as the lengths of pendulums are measured from the point of suspension to the point of oscillation, this point of oscillation in strings must depend on the tension of the string. When the string is slack the distance between the point of suspension and oscillation, or between one of the pegs to which the string is fastened and the middle of the string, must be greater than when the string is tight. But perhaps the true principle is, that each string possesses elasticity only to a limited degree; and that when stretched tight, a certain portion of its elastic power is exerted lengthwise; and, therefore, when struck, there will be less to exert laterally in the vibration—it will consequently vibrate in less time. It may be possible, therefore, to make a string so tight, that all its elasticity shall be exerted longitudinally; so that when struck it will not vibrate but break.

"If the lengths and weights of two chords are the same, their times of vibrations will be inversely as the square roots of the forces with which they are stretched; and the number of vibrations which they perform in the same time, directly as those square roots. So also the tension and the weight remaining the same, the celerity of the vibration is inversely as the square root of the length, or, the tension and weight per inch remaining the same, the celerity of vibration is inversely as the length. If 8 strings be such that the number of vibrations, which they perform in a given time be as the numbers 24, 27, 30, 32, 36, 40, 45, 48, the sounds of the first seven will be perceived as increasing in acuteness one above another from the first to the last, and will yield the notes from the combination of which all musical effects are produced. The tone is not affected by the extent of the vibrations, but merely by their time. The loudness of their sound is supposed to depend on the greater extent of vibrations. The last of the 8 strings will sound what is called the octave above the first; and the same series may be repeated

again between the number 48, and its double 96, and each note will be the octave to its corresponding note in the first interval; the numbers of vibrations will be 54, 60, 64, 72, 80, 90, 96, and it is evident that this series may be continued either down or up without limit. All musical sounds are computed to be contained within 10 octaves; so that the number of vibrations in a given time, that yield the gravest note, is to that which yields the most acute, as 1 to 2^{10} or 1 to 1024." See Playfair's Outlines of Natural Philosophy.

Large instruments, and long, thick, and slack strings, therefore, vibrate slowly, or only once; while instruments of diminutive size, and very short, small, and tight strings vibrate above a thousand times;—the former producing grave and deep tones, and the latter sharp and acute;—hence that screw-twisting and ear-torturing process that attends the tuning of stringed instruments;—and all the variety of contrivances seen in musical instruments, which are, first, for producing the above octaves; and, secondly, for playing the tones longer or shorter, when they are called notes, so as to produce such harmonious combinations of regularly recurring sounds as we call a *tune*, an *air*, or a *melody*.

The above divisions in the length of the original long string are far from being arbitrary—they are even pointed out by Nature herself; for, should a rope of 30 or 40 feet in length be stretched very tight and struck, it will not vibrate uniformly between end and end; but will divide itself into portions:—some vibrating and some at rest,—the latter acting as bridges or stops to the former. Suppose the length of the rope to be 60; then the lengths of the vibrating parts must be 30, 20 and 12. For the sounds emitted are the octave, the twelfth or octave of the fifth, and the seventeenth major or double octave of the third major of the principal sound produced by the whole rope. It is supposed to be the tendency of strings to move in this manner that produces the wild and melodious harmony of the Eolian harp; for, we not only hear the natural sound of each string, but its octave, twelfth, and seventeenth. "Harmony, (says a writer in the Edinburgh Review,) is not an adventitious quality in sonorous bodies, but is in some sense inherent in every sound, however produced. Every sound is as much made up of three component parts as a ray of light is composed of seven (three) primary colours. In many sonorous bodies, these sounds may be made distinctly audible—as in the

toll of a great bell,—where amid the vibrations of the primary or fundamental note, its 12 and 17 are distinctly heard—that is, the note with its 3rd and 5th composing the full harmony are generated by the vibrations of what appears to inattentive ears to be only a simple sound." Something of the same kind may be observed in the report of cannon when heard from a distance. When near all secondary vibrations are confounded in one crack; but when heard from the distance of 10 or 20 miles, "it is a grave sound, which may be compared to a determinate musical sound, and instead of being instantaneous, it begins softly, swells to its greatest loudness, and then dies away growling. Nearly the same may be observed with respect to a clap of thunder."

Another remarkable circumstance in the nature of sound, is, that when an elastic propulsion of the air producing a certain tone strikes any sonorous body or musical instrument, which if struck in any other manner would produce that tone, it communicates the sound to that body or instrument, while it breaks against or passes over all others not in unison without producing any effect. The strings of the Eolian harp are of the same length, and are tuned in unison,—if one string is, therefore, struck, the whole will vibrate or produce sound; but if only two are in unison, and one of them be struck, the other only will vibrate. This may be proved by hanging pieces of paper on all the strings; when, if one be struck, the paper will immediately fly off the other in unison with it, but will remain undisturbed upon the rest. Though the strings all produce the same combinations of natural concords; yet, as the wind that plays upon them is perpetually varying its intensity, its sportive sweeps "produce a variety and sweetness of harmony, which, heard in the stillness of evening may almost be mistaken for an unearthly music."

To this sympathy in the elastic properties of matter it is owing that one thing, and perhaps only that one in a room will begin to dance, vibrate, or emit sound to one particular note of an organ or any other instrument, while all the other notes have no effect upon it. These corresponding notes are called the key notes; and such foundation has this in nature, that it is not confined to inanimate objects. A dog will begin to howl at one particular note, though indifferent to all the rest of the gamut; and even man himself has the key note to each of his passions; and hence it is, that his soul is so moved with music, and that

he is often compelled, even in defiance of himself, to laugh with those that laugh and weep with those that weep.

7. THE HUMAN EAR.

The human ear consists of a great many parts, each of which has its appropriate use. The external or visible part is called the *concha;* and its office is to collect the impulses of the air, to condense and direct them into the external orifice, called the *auditory canal.* Without this external part the sensation of sound would be indistinct, and little better than a continual murmur. The concha and auditory canal form what is called the *external ear.*

At the bottom of the auditory canal is a membrane stretched tight across the orifice, and which separates the internal from the external ear. This is called the *membranum tympani,* top or pelt of the drum of the ear. Beyond it is a large cavity called the *tympanum* or drum. The office of the membrane, is, when struck by the impulses of the air, to vibrate like the top of a drum. It is furnished with a radiated muscle at its centre, by the aid of which it is supposed to be tightened, if the sound be a whisper; or relaxed, if a crack. In the human ear, the membrane is circular and of about half an inch diameter, the radii are therefore of equal length; but in most other animals, especially the ox and the elephant, its form is elliptical, and the centre of the muscle is in one of the foci. The longer radii are supposed to enable such animals to hear low sounds much better than man:—but it is also supposed that, from the peculiar shape of the human membrane, man is enabled to receive pleasure from music; the loud or quick notes having no particular effect on the lion or the elephant, while the low and flat notes rouse all their ferine propensities.

The drum or tympanum is not a vacuum; but contains the auditory apparatus, consisting of four small bones; and the remaining interstices and sinuses are filled with air. Had this air been confined, it would have expanded and condensed according to the temperature, at the hazard of bursting the membrane; and if it had been open to the external air, the cold air would have been continually rushing in. To prevent these inconveniences a very small tube opens from this cavity into the back part of the mouth, called the *eustachian tube.* Hence, we hear better with our mouths open; or, if we put a watch into

the mouth and stop the ears, we can perceive it to beat more distinctly than in any other way.

Besides the eustachian tube, the cavity of the tympanum has sinuses called the *mastoid* cells; and two passages leading up to the brain—one called the *fenestra ovalis*, and the other the *fenestra rotunda*. These two communicate with one general but irregular cavity called the *labyrinth*. But that from the fenestra ovalis, takes the principal part, and separates into three divisions, viz. the *vestibule*, the three *semilunar canals*, and the *coclea*. This last is the most remarkable, since it takes a spiral course upwards towards the brain, not unlike the shell of a snail; and is moreover divided by a thin lamina of chords. The chords are the auditory nerves that communicate with the brain. They are disposed across the cavity of the coclea; and as it tapers up to the top, of course, the lower strings, are longer than the upper: --the whole bearing a similarity to the chords of the diatonic scale. Hence, they have often been compared to the strings of a harp.

The four small bones inside the tympanum constitute a very curious piece of mechanism. They are called the *malleus* or hammer, the *incus* or anvil, the roundish or *oval bone*, and the *stapes* or stirrup. The body of the hammer is placed in the upper part of the tympanum, and a long process, called the handle, proceeds to the membrane, to which it is fixed. The incus, to the body of which the hammer is articulated, consists of two legs; and is not unlike a tooth with a double fang. It is the largest and strongest of the four. Its shorter leg is fixed near the entrance of the mastoid process; and the longer takes the direction of the handle of the malleus, to which it is joined by a ligament; and, being bent inward, it receives the small oval bone, that combines it with the stapes. This last bone has two legs, bent almost into a circle; and where they unite at the basis they cover the fenestra ovalis.

The whole is put in motion by the impulses of the external air striking the membranum tympani, which works the handle of the hammer as a lever—the short arm of the lever moving the long leg of the anvil attached to it by the ligament. The anvil moves the stapes—the oval bone merely performing the office of a joint; and the stapes moves the air contained in the spiral, or upper part of the labyrinth called the coclea, on one side of the chords; while the air on the other side is moved by its communication through the fenestra rotunda with that of the

tympanum. Thus the chords are struck on both sides at once; and each one perhaps serves as a key note to the vibration of the external air, and conveys its own certain and peculiar impression to the brain: the longest chords transmitting the grave tones, and the shortest the most acute. What a piece of mechanism is man!

8. CLOUDS.

CLOUDS are collections of vapours, that ascend from the earth, and are aggregated by the electric fluids. There are three distinct and primary modifications of clouds as they exist in settled weather; each of which has received an appropriate appellation as follows;—The *cirrus*, or pencilled cloud; the *cumulus*, or pack cloud; and the *stratus*, unformed or mist cloud. In a less settled state of the atmosphere, as may be seen a little before the commencement of and sometimes during rain, these combine to form four other secondary modifications, viz. the *cirro-cumulus;* the *cirro-stratus;* the *cumulo-stratus;* and the *nimbus*, cirro-cumulo-stratus—or rain cloud.

The *cirrus* is the most elevated of all the clouds, and has the least density, and the greatest variety of extent and direction. It consists of all those beautifully pencilled streaks, or wreaths, dappled lobes, or tufts, which frequently amuse us with their fantastic shapes in mild weather, or after the sky has been a long time clear. At what height the most elevated are, is not known. Aeronauts at great altitudes, even when the cumulus appeared beneath their feet like small silvery specks upon the earth's surface, have seen the cirrus apparently as high above their heads, as when it was viewed from the earth. As its elevation is so great, there is little doubt that the aqueous particles, of which it is composed, are congealed and as dry as dust. The shape tends also to corroborate this opinion—it being an exact resemblance of the curious arrangements, which very small and dry dust, as chalk or vermillion, assumes, when sprinkled upon a slightly electrified cake of wax or resin. But as the cirri always change their form when they descend; we may suppose that they, in coming below the point of congelation, are thawed; and, in this case, pass into the cirro-stratus modification.

The duration of the cirri clouds is very variable. It is the longest when they appear alone, and at great elevations, and the shortest, when they are found in the lower regions, and in the

vicinity of other clouds. They sometimes only continue a few minutes; and at other times remain for some hours. They generally form to the leeward, and increase in the windward direction; but principally so in fair weather, with slight variable breezes, at which time the sky is seldom clear of them. In continued wet weather, horizontal sheets of this cloud are rapidly formed, which as quickly change to the cirro-stratus.

The *cumulus* is the dense black cloud, which rides upon the stream of air, that sweeps the face of the earth. It generally takes its rise from a speck not larger than a man's hand, around which its packs accumulate. The lower surface appears plain as if sitting on the wind; while the higher, lifts its head in conical and hemispherical heaps. By this cloud are the water spouts emptied, and their contents carried over the land; and from it is the thunder-bolt hurled, and the torrent poured down. But it is employed for more benign and gentle purposes. It carries the produce of evaporation to distant places where it is most needed; and often serves as a skreen to protect the earth from the scorching heat of the sun. On this occasion, it generally makes its appearance in the forenoon; spreads out its broad, sable wings through the hottest part of the afternoon; and totally disappears about sun set. But should it still increase, thunder generally follows during the night. When the cumulus changes its shape rapidly; and the cirri above accumulate, and hover down to it, resting on its top as on a mountain—rain may be expected. As also, when it forms to leeward in a strong wind, both rain and a calm generally succeed.

The *stratus* is the lowest of the clouds. It is less dense than the cumulus, but more compact than the cirrus. It frequently rests on the ground, and then goes by the name of *fog* or *mist*. It is often seen slowly creeping up the sides of mountains, hanging so low that we can see their summits above it. It is properly the cloud of the night; generally, in warm weather, rising after sun-set; and in calm evenings, it loves to move slowly along the bottoms of the valleys; and afterwards to spread itself into sheets like an inundation of water. On such occasions it is mostly on the plains contiguous to rivers: the water after sun-set, being of a higher temperature than the superincumbent air, thus sends off its caloric combined with vapour, which fertilises the adjacent land.

This evening stratus differs from the dew. Dew is composed of the particles of evaporation, caused by the sun's rays. These

particles, having ascended only a little way above the earth's surface when the sun sets, and the supply of caloric that rendered them buoyant being thus cut off, gradually descend to the earth. But in windy weather, little or no dew is seen; by reason of the wind carrying off the vapour, and enabling it to gain the upper regions of the air, as fast as it is generated. The time of dew-fall generally continues an hour or two after sun-set, when the air again becomes dry; but it sometimes, and especially in warm climates, continues to fall the whole night. This is the case in some parts of Arabia, in Egypt, Peru and Chili. In the latter two countries, the stratus, composed of the vapour passing from the Pacific to the Andes, continues all the day at a considerable elevation, but being arrested by the nocturnal cold, it slowly descends as dew and supplies the want of rain. In the deserts of Arabia the dew will sometimes wet travellers to the skin.

The *cirro-cumulus*, the first of the secondary modification, is formed from a number of cirri, whose fibres collapse as the whole descend to a lower station in the atmosphere; assuming at the same time the cumulo shape, but in small packs well defined, and closely arranged in horizontal strata. While undergoing this change, they frequently present a most beautiful sky, exhibiting small silvery beds at different altitudes. This cloud is the most frequent in summer; and is almost a sure prognostic of warm, dry weather; especially if it ascend, assume the cirro-shape, and then disappear. It is also sometimes seen during the intervals between showers; and often spreads itself into sheets when it becomes

The *cirro-stratus*. While it is undergoing this change, all the beds unite, frequently exhibiting the appearance of shoals of fish; and on such occasions, it has sometimes been called the mackerel-back cloud. This modification of clouds precedes wind and rain; is always seen during the intervals of storms; and, when it accumulates rapidly, we may be sure the storm is at hand. In this cloud are exhibited the halo and mock-sun; hence, these phenomena are always considered as sure prognostics of foul weather.

The *cumulo-stratus*, is, the cumulus bursting or spreading about on its upper surface; on which occasions, if it accumulate rapidly, a cirro-stratus is frequently seen resting on its summit; but they soon spread and mix together. When this cloud is very high and dense, the appearance of bursting is

reversed; and then, it may not unfitly be compared to a mushroom, with a broad head and short thick stem. It generally precedes thunder storms, or showers of snow or hail. Sometimes the cumulus may be seen to protrude upwards through the interstices of the higher clouds; and while in this condition, should the whole pass off with the wind, so as we can see their tops along the verge of the horizon, they present to the imagination mountains covered with snow, interspersed with dark ridges, and rocks and towers jutting out of, or projecting over seas and lakes.

The *nimbus* or rain cloud. Before rain reaches the earth, a manifest change takes place in the modification of the whole system of clouds. They burst, or change from their cumulo or cirro forms to the sheet clouds; and a moisture of the air, or the stratus touching the earth, for a short time, precedes the drops. When the rain cloud is formed over our heads, we cannot see this change going on; only a turbidness or dense sheet is visible; but, when we have a profile view, we can see the whole process. In thunder storms, two dense clouds may frequently be seen rushing together; when their contact, or dissolution is announced by the flash. As the vapours are collected into clouds by the electric fluids, so they always descend in rain as soon as these fluids are discharged. See Chap. XVI. s. 8.; also "Researches about Atmospheric Phenomena," by T. Foster, L. S. F.

9. THE QUANTITY AND DISTRIBUTION OF RAIN.

The quantity of rain which, falls annually, is found by careful observation to correspond, pretty nearly, with the quantity of water evaporated. It is greatest at the equator, and decreases as we approach the poles; and that, nearly in the same proportion as evaporation. The depth of rain falling annually at different places, is as follows: Granada, West Indies, 126in. Cape Francois 120. Calcutta 81. Rome 39. England 35. St. Petersburgh 16. The mean annual quantity, falling at 147 places situated between the two parallels 11 and 60deg. N. Lat. is 34,7 inches. Hence 34in. are assumed as the mean depth, that falls all over the superficies of the globe. This is one inch less than the water evaporated; which may be considered as falling in dew, and as making up the enormous quantity, frequently precipitated on the tops and sides of inaccessible mountains.

The superficies of the globe is estimated at 170,981,012 square miles; of which 52,745,253 are dry land, the rest are ice and water. The quantity of rain falling is 91,751 cubic miles of water; so that 40,960 cubic miles will fall upon the land; of which 13,140 are supposed to be carried back by the rivers to the sea. From this it is evident, that more water, by at least this last mentioned quantity, must be evaporated from the sea, than falls upon it in rain; and must be dispersed by the clouds over the land; otherwise, the land, affording such a quantity to the sea, would soon have its moisture exhausted.

In cold climates the atmosphere can hardly hold the vapour in suspension; so that hazy weather is very prevalent, heavy rain very uncommon, but rainy days very numerous. In the torrid zone the rainy days are comparatively few, though the rain falling is so enormously great. They are the fewest at the equator; between the parallels of 12 and 43 degrees, the mean annual number is 78. Between 43 and 46 degrees, 103. From 46 to 50 degrees, 134. And between the latitudes of 50 and 60 degrees, 161. The number of rainy days in winter is mostly greater than in summer; though the quantity of rain falling is always less.

More rain falls in mountainous regions than on plains. On some of the highest mountains in Britain a day seldom passes without rain. Among the Andes it is said to rain almost perpetually; while at a short distance, viz. on the plains of Peru and Chili, it seldom rains; also in Egypt, rain is very uncommon.

The quantity of rain falling on the western coast of England, is, half as much more than that which falls on the inland counties. The wind not being able to bear its load of vapours, collected from the Atlantic, over the hills, deposits it there in rain (see Chap. 16. s. 8). In warm climates, the countries situated at the foot of mountains often suffer dreadfully by floods thus occasioned. The regions near the Andes; the estates in some parts of the colonies in New South Wales adjoining to the Blue Mountains; and the valleys of all mountainous regions,—have often been devastated by this means. Even in England similar instances are not wanting. In the year 1771, a strong S. E. wind blew over the northern counties, attended with small but rather heavy rain, and a very dense atmosphere; being impeded or attracted by the Cross-Fells, in Cumberland,—there precipitated its load; which caused so great a swell in the rivers, that have their rise among these mountains, as to carry away

nearly all the bridges. This occurrence is known in the north by the name of "The Great Flood."

The quantity of rain falling in islands, is proportionately much greater than that falling on continents. It is the greatest in the West India isles; but even in Ireland it is found to be one half greater, than that which falls in the inland counties of England.

In the torrid zone, the wet and dry seasons divide the year,—there being no such distinction as our summer and winter. As the rays of the sun are the cause of evaporation; so the sun always draws a vast quantity of vapour after him, which is precipitated in rain. The wet season generally commences with the sun's approach to the zenith. The Abyssinian rains, which are the causes of the inundation of the Nile, last from April to September; but for the first three months the rain is only in the night. The inundation in Egypt, begins at present about the 17th of June; it increases for forty days, and subsides in the same time; but the ancient accounts, as well as some modern ones, assign a longer duration to it. The river Amazon rises and falls at the same times as the Nile. The Ganges, the Indus, the Euphrates, the rivers of Ava or Pegu, and many other rivers have also considerable inundations at regular periods.

The expansion of the atmosphere by evaporation, and its subsequent contraction, when the vapour is discharged in rain, we assigned, Chap. VI, s. 12, as the second cause of wind. Whatever quantity of vapour atmospheric air contains, its bulk is always increased in proportion to the volume of that vapour. In moist places, therefore, where evaporation is very extensive, the swell of the atmosphere must be considerable; which must cause a lateral motion in the air. Also, when clouds are collected, especially when they are so condensed as to descend to a lower region, there must be an outward pressure and motion of the air immediately beneath them. Nevertheless some of these currents must be so slight as hardly to merit the name of winds. The weight of the atmosphere, immediately preceding a very large fall of rain, is equal to 30 feet of water;—a fall of six inches depth of rain will, therefore, be in vapour equal to a sixtieth part of its weight; and a little more than a sixtieth part of its bulk, (for vapour has less specific gravity than air); consequently, when the atmosphere returns to its equilibrium, there will be this vacancy of one-sixtieth part to fill up, which

must occasion a considerable current in the surrounding air, and, of course, a proportionate wind. For the ascent of the Barometer after great falls of rain, see Chap. XVI. s. 11.

CHAP. VIII.

Optics, or the Mechanical Laws of Light.

1. The Velocity, Extent, and Direction of Light. 2. Refracted Light. 3. The Prismatic Colours. 4. The Rainbow. 5. Reflected Light. 6. The Halo, Corona, and Mock Sun. 7. The Lens and Burning Glass. 8. The Eye. 9. Optical Instruments.

1. THE VELOCITY, EXTENT, AND DIRECTION OF LIGHT.

The real nature of light is one of those subjects which philosophy has yet to explain; although it is one, on which the most able and acute of her cultivators has bestowed a great deal of attention. Sir Isaac Newton demonstrated all its mechanical laws; but as chemistry was in his day only in its infancy, and as the origin of light is undoubtedly among the electro-chemical principles, we need not wonder if that great man left this subject nearly as he found it. The sun is no doubt the great fountain of light; but to the atmosphere we are indebted for the full blaze of day; for, was it not for the agency of the atmosphere, we should see the sun but as a bright spot, and when we turned our backs towards him, should be in total darkness: just as when we look at the sun and the contrary way through a piece of smoked or stained glass.

However, it is the mechanical properties of light which we have now to examine; and these are as plain and demonstrable as any other mathematical subject. The most obvious of them, are,—that light is transmitted in straight lines from the sun; and that it travels nearly at the rate of 200,000 miles in a second of time. Some idea of the amazing swiftness of its pro-

gress may be conceived from the consideration, that it performs the journey from the sun to the earth in little more than eight minutes; but that a cannon ball, projected from the sun, and travelling at the usual velocity given by gunpowder, would not reach the earth in 30 years.

If light, then, consist of particles, how infinitely small must they be; coming with such velocity and entering the eye, the most delicate and sensible organ of the body, without causing any great degree of uneasiness! "If a particle," says Thompson in his Elements of Chemistry, "weighed a thousandth part of a grain, its force would be equal to that of a musket ball; were it the millionth part of a grain, it would destroy every thing against which it struck. If it weighed a millionth part of that, it would still have a very sensible force; but how much less must it be when it makes no impression upon an organ so very delicate as the eye? We are certain, then, that no particle of light can weigh a millionth millionth part of a grain."

When light proceeds in every direction from a luminous body, as from a candle, its intensity is diminished as the square of its distance: thus, if the intensity at a certain distance be 1, then at twice that distance it is only $\frac{1}{4}$; at thrice $\frac{1}{9}$, and so on. upon this principle the light and heat of the planets were calculated in Chap. IV.

The rays of light while passing through the same medium are *rectilineal*; but on entering a different medium, they are diverted from the straight line, and are said to be *refracted*. When they strike a body, which neither permits them to pass through it, nor yet to enter, so as to be absorbed, they rebound from it, and are then said to be *reflected*.

Rays of light are said to be *parallel*, *converging*, or *diverging*. As all move in straight lines, those are *parallel* which do not in any part approach nearer to, or recede farther from each other. *Converging* rays are such as meet in a point, which is called the focus, and they are said to *diverge*, when they separate from a point or focus.

The rays of light always diverge from the focus at which they are generated; consequently, the rays of the sun, being under this law, diverge accordingly; but, because the sun is a million times larger than the earth, and at the distance of 95 millions of miles, the divergency of those comparatively few rays that strike the earth, is so very small, that they are always considered as parallel.

As pieces of glass can be fashioned with every variety of surface, by their assistance, and that of bright and polished surfaces, opticians can refract, unravel, reflect, condense and disperse the rays of light almost in any manner they please.

2. REFRACTED LIGHT.

The rays of light, while passing through the same medium, are rectilineal; but on entering a denser medium, they are, unless they strike it perpendicularly, diverted from the straight line; and are inclined to the perpendicular of that surface which they enter. But in passing from a denser to a rarer medium, they are declined from the perpendicular. Should they enter it perpendicularly, they pass on without being diverted from the straight line; so that, the more obliquely the rays of light strike a surface, the greater the refraction.

Let B C Fig. 30. represent a ray of light falling upon a denser medium L G; then, instead of passing forward to H, it is bent in the direction of I nearer to the perpendicular F C K: and on passing out of the denser medium is again diverted from the perpendicular. But if F C be an incidental ray it will pass straight forward to K.

When the rays of light coming from the sun strike the atmosphere as at *a* Fig. 31. they are bent downwards; and the most so when the sun is the lowest. This refraction is such that we can see the sun when all the disc is below the horison or 3 minutes before he rises, and the same length of time after he sets. What is meant by rising and setting, is, when a line from the solar centre to the spectator *b* would be at the horizon. If, then, while the sun is at the horizon, that is rising or setting, his rays on striking the atmosphere be bent downwards, those rays which reach the eye, will strike the surface of the atmosphere at considerably above the place where the direct line from the sun's centre cuts it; and as we are accustomed *to view every object in the direction in which the rays last strike the eye*, the sun will appear at that place where the rays strike the atmosphere, or at *c*, considerably above the place where the central line cuts the horizon; and, therefore, he will appear thus far above the horizon, while he is in fact but just upon it. The horizontal refraction is 34 minutes.

As the rays enter a denser medium when they strike the atmosphere; and their tendency is then to move in a direction

nearer to a perpendicular to that surface at which they enter, (the perpendicular in this case being the zenith and nadir line of the spectator;) consequently, as the sun rises above the horizon, the impinging rays will make a less angle with this vertical line; and therefore the higher the sun is, or the nearer to the vertex, the less is the refraction; so that, were he in the zenith there would be no refraction at all.

On account of this refraction we never see the heavenly bodies exactly at the place at which they are, unless when any one is in the zenith; and consequently in making astronomical observations, allowance is always made in the calculation for refraction according to the distance, that such bodies are from the vertical point.

To this refrangibility of light, twilight is principally owing; for when the sun is far below the horizon, even 18deg., the few rays, that strike the upper parts of the atmosphere, are much more bent downwards, on account of their striking it still more obliquely than when the sun is at the horizon; and thus a faint glimmering begins and ends the day. Were the light not thus refracted, we should have almost total darkness till the direct rays of the sun fell upon us, to the great injury of our eyesight. How wonderful are the contrivances of the Creator for the comfort of his creatures!

If the rays of light are refracted on entering the atmosphere, they are still more so in passing out of the atmosphere into a denser medium, as into water; considerably more so when they enter glass; and on entering diamond still more. This refraction may be easily exemplified by holding one end of a stick in different positions in water; or, if a basin with a shilling in it be placed upon a table; and a person stand at such a distance, and in such a position that he can see within an inch of the shilling at the bottom of the basin; and while he is in this position, should water be poured into the basin till it is four inches deep; the shilling will be visible, or appear by the rays of light being refracted, to be only three inches below the surface of the water.

On this principle the depth of clear water has often deceived and proved fatal to school boys in the act of bathing; but they, who are accustomed to shoot fish in water, are well acquainted with the deception; and always take aim at about one-fourth lower than the apparent distance of the fish from the surface.

3. THE PRISMATIC COLOURS.

A PRISM is a triangular bar of solid glass of the most pure and clear texture. Its sides or facets are about an inch broad and very accurately ground. While the rays of light enter at one of the sides, and pass out at either of the other, they are twice refracted: being refracted at each surface. But some of them are more refracted than others; and they then present different colours; hence called the *prismatic colours.* A prism simply held before the eyes, presents a sight of indescribable beauty; such as a person, who has not seen it, can form no idea of.

The rays of light are of three kinds: one kind producing heat, another light or colours and heat, and the third chemical effects. Should a room be completely darkened, except a hole A, Fig. 32. of only about an inch square in a window shutter; and a prism, B, be applied to this hole, so that the solar rays may fall upon one side, and in passing out at one of the other, be thrown upon a white sheet, C D, at the opposite side of the room; the 7 prismatic colours will be displayed thereon, as seen in the rainbow: this phenomenon is called the *spectrum.* The *red* is the lowest of the series, then the *orange,* the *yellow,* the *green,* the *blue,* the *indigo,* and the *violet* follow successively. If the whole height of the spectrum be divided into 360 parts, each colour will occupy as follows;—red 45, orange 27, yellow 48, green and blue each 60, indigo 40, and violet 80, of these rays, the red are the least refracted, and the violet the most.

When a thermometer is applied, the red rays are found to afford the most heat; but below the red, and even where there is neither light nor colour, the mercury will rise considerably higher than when held in the red. (see Chap. XIV. s. 5). Hence it is concluded, that there are rays coming from the sun that produce heat only, which are thence named the *calorific rays.* The other colours have successively less effect on the thermometer than the red; that of the violet is imperceptible. But as the sun's rays have the power of detaching oxygen from its combinations; or, as we would say in common language, of destroying or changing colours; so the order of rays producing this effect, is the reverse of the calorific rays. The violet are the most powerful; but there are invisible rays beyond these, producing neither light nor heat, which are in this respect still more energetic;—they are therefore called the *deoxygenizing* rays.

To account for the different colours we see in the face of nature, it is supposed, that certain substances absorb some of the rays of light, and reflect the rest to the eye. Thus, a red surface reflects the rays producing the red, and absorbs all the rest; and so of the others. If a surface absorb all the rays, reflecting none, it is *black*; and if it reflect all, and absorb none, it is *white*: hence, black and white are said to be no colours; the one leaving a total blank on the optic nerve, and the other pouring all the rays of light upon it.

Should due proportions of paints of all the seven colours be blended together, the compound will be a white; though a little dingy on account of the impurity of artificial colours. But the best method of experimentalizing on this subject, is, to make a circle on a piece of white paste board; and set off degrees of its circumference corresponding with the proportional numbers of the different colours on the spectrum; painting each sector of the circle with its respective colour, or covering it with pieces of coloured cloth; then with a pin through the centre, spin it very rapidly round, and the party coloured circle will appear almost white.

Four of the above 7 colours can be produced artificially from the red, yellow, and violet; which three, have consequently sometimes been called the *primary* colours; and the others, supposed to be but mixtures on the spectrum, have been denominated *secondary*.

4. THE RAINBOW.

The rainbow is by far the most beautiful of the aerial phenomena. It is caused by the rays of the sun falling upon a shower of rain, when the drops act as prisms and refract the light.

The spectator must therefore be stationed between the shower and the sun, with his back to the latter when the bow will appear to bestride the shower. As all the circular parts appear at exactly the same distance from the eye; were lines drawn to the out edge of the bow they would form a cone, or part of one, with the apex at the eye.

The size of the bow or height of the arch depends upon the elevation of the sun. If the sun be high, the rainbow is low; and if the sun be low the rainbow is high, more of the circular base of the cone being seen; so that, should the spectator be on a mountain, while a shower is falling in the adjoining valley, he

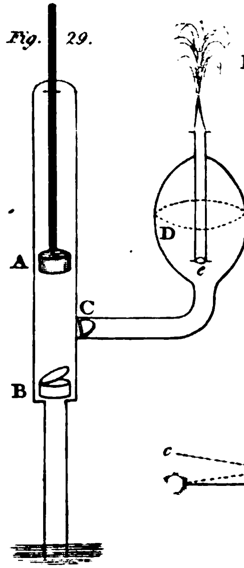


Fig. 29.

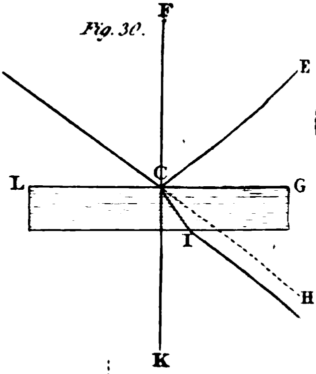


Fig. 30.

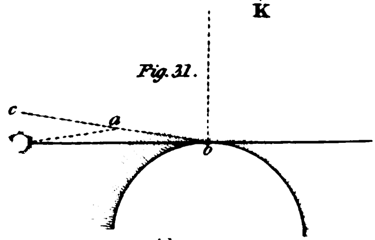


Fig. 31.

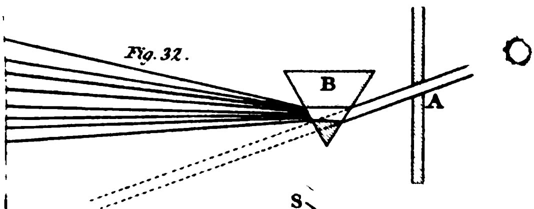


Fig. 32.

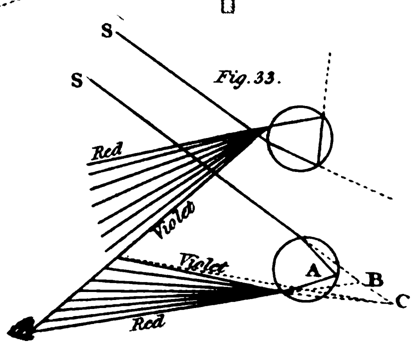
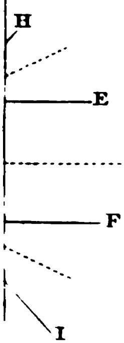


Fig. 33.



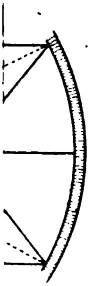
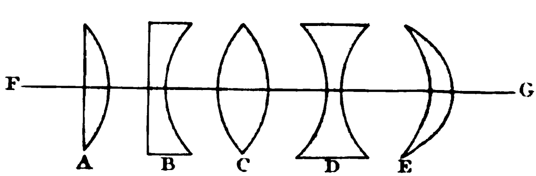


Fig. 36.



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would see the whole circle, instead of the arch generally seen on the plains. In the spray of the sea or of cataracts, in the shower of an artificial fountain, or in the drops of dew that bespangle the grass, the circle is mostly seen complete.

Two rainbows are generally seen at the same time; the exterior one being much the fainter, and the order of the colours are inverted.

For the production of the interior bow, the solar beam strikes the drop A near the upper surface, (see Fig. 33.) is a little refracted downwards while passing through it; and, when it comes to the opposite side, some of the rays pass out, and the rest are reflected back towards the spectator, but rather more to the bottom of the drop; and on quitting the drop are again refracted rather upwards, and are separated into the prismatic colours. But as the colours are refracted at different angles, only one colour from the same drop can at the same time strike the eye. The line of the red rays, coming from the drop, makes an angle with the beam, that falls upon the drop from the sun, of 42 deg. 2 min., the angular point B being beyond the drop. But the violet rays make an angle of only 40 deg. 17 min.; and, therefore, as the red is the lowest in the order of the bow, the drops which produce the violet will be the lowest in the shower: coming from the angular point C.

This may be easily demonstrated by suspending, in the sunshine, a hollow glass globe filled with water; at such a height that it will appear red, (the spectator having his back to the sun;) the angle of the incidental rays, and those reflected from the red globe to the eye, will now be found to be 42 deg. 2 min. Should the globe be a little lowered, the orange will appear, then the yellow, and lastly the violet at an angle of 40 deg. 17 min. Thus; after the rays have been twice refracted and once reflected, they produce the *interior* bow.

But for forming the *exterior* bow, the rays are twice refracted and twice reflected; and as light always loses about half by each reflection, so the exterior or secondary bow is much fainter than the interior or primary one.

The drops, producing the secondary, are much higher than those producing the primary. The solar rays strike them partly on the under side, and are reflected upwards; then some of the rays from the opposite side of the drop are reflected towards the upper part of the drop; and some of these back to a little above where the incidental rays enter; and thence, crossing these

incidental rays, are refracted downwards to the eye;—the red rays making an angle with the solar beam of 51 deg. and the violet of 54 deg. As the colours of this bow are inverted the order of the drops are so likewise: those producing the violet having the greatest elevation.

From the above remarks, it will appear, that no two persons can see the same rainbow; for different drops must refract and reflect the rays to the eyes of each. The falling drops may each produce all the 7 colours, one after the other; but the mind loses the idea of succession, just as when a fire-brand is rapidly hurled round, the appearance of a permanent circle or zone is presented.

A lunar rainbow is sometimes seen; but, though beautiful, its colours are very faint.

5. REFLECTED LIGHT.

WHEN the rays of light fall obliquely upon any reflecting surface they rebound from it, in the opposite direction, at the same angle; or, if they fall perpendicularly, they are reflected perpendicularly; hence it is an established law in optics, which holds good in all kinds of surfaces, and whether the incidental rays be convergent or divergent, *that the angle of reflection is equal to the angle of incidence.* Let B C, Fig. 30, be an incidental ray of light striking the reflecting surface L G; it will rebound from it in the direction of C E: making the angle of reflection E C G, equal to the angle of incidence B C L.

However, it is found, that even from the most perfectly reflecting surface, which is that of highly polished metal, light, by reflection, loses half of its intensity.

There are three kinds of reflecting surfaces,—the *plane* or flat, the *convex* or spherical, and the *concave* or hollow spherical.

All bright, smooth or polished and level surfaces are of the first kind. A common looking-glass, wherein the brightness of the metallic surface is preserved by its contact with the glass, is the most known. The rays are merely reflected from this mirror with the same angle at which they strike it; but by having a number of them disposed at angles corresponding with each other, the image of an object has been reflected from one room to another; and an ignorant spectator almost persuaded that the operator could see through a wall.

By the angle of reflection being equal to the angle of incidence, a person is enabled to see his whole length in a glass,

which is but half his length. But this can only be done when the glass is so placed, that the rays coming from every part of the body shall so strike it, as when reflected, they may reach the eye. In this case, by some inexplicable faculty of the mind, we see along every reflected ray to the glass, and from the glass back to the person along its corresponding incidental ray; and, therefore, at whatever distance we stand from the glass, every part of the person appears at just the same distance beyond it.

Convex mirrors are either polished spheres or slices cut from them; and concave, are parts or slices of hollow spheres; so that the centre of concavity or convexity is the centre of the whole sphere.

Parallel rays falling upon a convex sphere are rendered divergent; and diverging rays are rendered more divergent:—but, converging rays are made either parallel or less convergent. Now as the angle of reflection is equal to the angle of incidence, the ray reflected from a convex mirror will rebound outwardly; but as the image is seen behind the mirror, the line of the reflected rays are supposed to be extended through the mirror, and they will all, consequently, meet a little behind it, at the point where the image is seen, called the *focus*. This point, for parallel rays, is at one fourth the length of the diameter of the sphere; and the distance is called the focal distance.

Let A B fig. 34 represent a convex mirror; C the centre of convexity, and E D, F G, parallel rays falling upon it: then, as they are reflected outwardly, E D will be in the direction of D H, and F G in the direction of G I: diverging from the point N which is the focal point where the image is seen. Should H D and I G be the convergent incidental rays, then, the parallel rays D E and G F will be the reflected rays.

As parallel rays are made divergent, it is evident, that those which strike the mirror towards the edges, cannot enter the eye; and, in short, only those can reach the eye which strike its centre; for then they are reflected perpendicularly. But when a person views himself in such a mirror, rays from all parts of his body will strike all parts of the convex surface; and therefore, some of them must be convergent—must strike near the centre of the mirror, or between G and D, and at such an angle, that when they rebound they must enter the eye;—and, as we are accustomed to view objects in the direction of the rays

which last strike the eye, therefore, a person will see his own image contracted to just the length which these rays occupy on the mirror.

Parallel rays reflected from a concave mirror, are convergent; divergent rays are also made convergent, or parallel; and convergent rays are made more convergent. As the rays rebound outwardly from a convex mirror, so they rebound inwardly from a concave one, and meet at a point in the front. If the incident rays be parallel, as fig. 35, the focal distance is at *a*, or at one fourth of the diameter of the whole sphere, if they are convergent, the focal distance is less; and if divergent, it is greater—or the image is seen at the same distance as the object, as in plane mirrors. Now as the lines of the reflected rays, when continued through the mirror, will diverge behind it, a person will see his image distorted or magnified in a concave mirror as he sees it contracted in the convex.

The rays of an object do not come parallel to the surface of a concave mirror; for rays from every part of the object will strike every part of the mirror; and therefore, being reflected, which must be inwardly, they will meet at a focus at the front, where they will cross each other; and a person placed farther from the mirror, but in the line, will see his inverted image pendent in the air.

When the object is more remote from the mirror than the centre of its concavity, the image will be less than the object, and between it and the mirror; and when the object is nearer than the centre of the concavity, the image will be more remote and magnified. Should the object be at the centre of concavity, then it and the image are coincident.

A person, a little beyond the centre of concavity, will see his own contracted image inverted between him and the mirror. If he stretch his hand towards the mirror, one hand of the image will be held out towards him: if his hand be at the centre of concavity the hand of the image will be of the same size, and will coincide with the real hand. Should he stretch his hand beyond the centre, the hands will pass: if to one side, the hand of the image will move to the other.

A bright mahogany table, placed in the focus of a mirror, that hangs against the wall on the side of the room directly opposite the fire, will have the image of the fire erect upon it. A person standing by the table will see only a long beam of

light; but should he be stationed nearer the fire, a little to one side, he will see as it were a fire on the table.

A great many deceptions have been practised with the concave mirror; for by reason of the angular law, both the mirror and the object may be hid: when the unwary spectator, catching at an empty shadow in the air, and the operator instantly substituting some other object, instead of laying hold of a bird or a nosegay as was expected, a snake or a death's head snatckes at his hand: while, at the same time, a byestander will see nothing of the image; because none of the reflected rays that form it, enter his eyes.

6. HALO, CORONA, AND MOCKSUN.

These originate from the solar or lunar beams, being refracted through or reflected from the cloud called the cirrostratus.

The *halo* is an extensive luminous ring round the sun or moon, but more frequently the latter, while the luminary appears at the centre. The rays producing it are refracted, but not distinctly separated into the colours. The halo varies in size according to the elevation of the cloud: the higher the cloud the less the diameter of the halo.

The *corona* is sometimes seen in the centre of the halo, especially that of the moon, but oftener appears alone. The luminary is seen as it were disguised in a muff, with the prismatic colours faintly exhibited round the edges. The size of the corona varies considerably, but it is never much more than 10 degrees diameter.

The *mocksun* or parhelion, and the mockmoon or paraselene, seem to be entirely owing to reflection; though they are not yet well accounted for, by reason of their being seldom seen, and of the want of knowledge in the science of optics in those who have seen them. When the parhelia have been observed in England, the sun was not far above the horizon, and a dense cloud either immediately beneath, or nearly between the sun and the spectator; so that the solar image seemed as it were reflected from the bosom of the cloud. On such occasions there is generally an extensive halo of 60 or 80 degrees diameter, but the circle is seldom complete. And in the circumference of this halo are the mocksuns; one at every quadrant of the circle; each having a halo round it, with sometimes a co-

rona, and often a conical tail towards the real sun, They have frequently been exhibited so distinctly, that the astonished spectator has been at a loss to distinguish the *true* sun from the *false* ones.

As parhelia and paraselenai have only been seen where the sun or moon was a little way above the horizon, (for at great elevations it would be impossible for the reflected rays to reach the eye), so they are of very frequent occurrence in the latitude of Hudson's Bay, where the sun never rises very high. Mr. Fisher, in his account of Capt. Parry's first expedition, remarked, that when the mocksuns were exhibited, there was always a little snow falling, but that it was as small and dry as dust; and in all probability, when they are seen in England, the nimbus cloud is always beneath the cirrostratus.

Artificial haloes may be formed by spreading over glass a little alum dissolved in water, which crystallizes, and exhibits, when the sun is viewed through it, three haloes: the natural ones are, therefore, probably caused by frozen vapours.

7. THE LENS AND BURNING GLASS.

A PIECE of glass fashioned by the optical art, so as to change the direction of the rays of light, is called the *lens*. There are two kinds of lenses, (see Fig. 36.) named according to their form, as the *plano convex* A, and *double convex* C, the *plano concave* B, and *double concave* D; and the miniscus E. The axis F G, of a lens is the line passing through its centre and focus, and is extended to any distance on each side.

A *plano-convex* has one side flat and the other convex, being a slice cut from a sphere. Parallel rays falling on the convex side, converge to a focus on the opposite side: the focal distance being the diameter of the whole sphere; see Fig. 37. A double convex is, as it were, the flat sides of two of these joined together. The effect is to make the rays converge at half the distance, or at the centre of the sphere, see Fig. 38. Should the inner surface belong to a slice from a less sphere than that of the outer one, the rays will converge to a point at a less distance than the centre of the sphere of the outer surface; and, if it be a part of a greater sphere than the outer one, then the focus will be beyond the central point of the outer sphere.

Should the rays pass through a similar lens placed at the same distance beyond the focus, as in Fig. 38,—they will be

rendered parallel. The rays from a candle are divergent; if, therefore, a candle be placed in the focus, the rays will be made parallel; if within the focal distance, they will continue divergent; and if placed at a greater distance than the focus, they will converge and form an inverted image of the candle a little beyond the focus at the opposite side, which may be exhibited on a sheet of white paper placed thereat. Converging rays, therefore, passing through a convex lens, will come to a point within the focal distance; and diverging, at a point beyond it.

The *plano-concave* and *double-concave* are the reverse of the single and double convex, being portions of a concave sphere; and their effect is to make the rays diverge as if they had come from a point at the opposite side or centre of the spherical concavity, thence called the virtual or imaginary focus. In a single concave this focal point is at the length of the whole diameter of the sphere, in a double concave it is only at half the distance of the plano, and the divergency of the rays are therefore double. See Fig. 39.

The miniscus is the common watch glass, being concave at one side and convex at the other. If the convexity and concavity have the same diameter, parallel rays will still be parallel; but as their diameters generally vary, so the rays entering at the convex surface, will, if the concavity as E in Fig. 36, have a greater diameter than the convexity, *diverge;* but if less, then they will *converge.*

The *double* convex lens is the burning glass; and acts on the principle of collecting the solar rays, scattered over a large surface, into a narrow space. Thus: a lens of 4in. diameter will collect the rays to a focus of less than one tenth of an inch diameter; and, consequently, the concentrated light and heat of that point will be 1600 times more intense than the common heat of the sun. A lens of as many feet diameter, with the focus a little more concentrated by a smaller lens, will cause a heat which scarcely any thing can resist; and which is only exceeded in intensity by the blow-pipe and galvanic apparatus.

Decanters, glass jugs, flasks, or any globular or bulbous shaped glass vessels, when filled with water, act as lenses; and furniture has sometimes been set on fire by their being casually left in the solar rays.

The effect of the solar rays, concentrated at the focus of a concave mirror, is the same as that of a lens; and plane mirrors

placed in the curve of a circle will produce the same effect. With 40 plane mirrors so disposed, Buffon is said to have burnt deal boards at the distance of 66 feet; and with 117, he melted silver. It is related of the philosopher Archimedes, that while the Romans besieged the city of Syracuse, he, with mirrors placed at the distance of a bow shot, set fire to their fleet as it lay in the harbour. It has been supposed that he did it with plane mirrors disposed as above.

8. THE EYE.

THE rays, that enter the human eye and produce vision, pass through a double convex lens, called the crystalline lens, and are subject to the laws we have been describing. But previously to the explanation of this, it will be necessary to give a description of the mechanism of the eye.

The eye consists of *three coats,* including *three humors..* The *first* or outside coat is called the *sclerotica,* and is a tough membraneous substance; but the visible part at the front is transparent and horny, and is called the *cornea.* Behind the cornea is the *first* or *aqueous* humor, covering the iris and touching the crystalline lens.

The *second* or middle coat, which is muscular, is called the *choroides*; but the front is the *iris,* with a hole in the middle for the aqueous humor. The colour of the internal part or that next the third coat, is black or very dark purple; and as it is seen through the crystalline lens or pupil,—the pupil seems to be of the same colour. But the colour of the *tapetum,* as this part of the choroides is called, varies in different animals.

The *third* or innermost coat, which lines the back part of the eye, is called the *retina.* It consists entirely of nerves forming a kind of network or filmy web. The nerves unite behind in a chord called the optic nerve; which, passing through the other two coats, ascends to the brain: see A, Fig. 40. At the front of this last coat is placed the pupil, or *second* humor called the *crystalline lens;* and in the concavity between it and the retina is the last, but considerably the largest humor, called the *vitreous* humor. The use of this last humor, seems to be for a stay to keep the lens steady, so that its focus may alway be at the retina.

The aqueous humor is the most fluid, resembling water. In it the iris seems to swim; so that it is divided into the interior and posterior aqueous humor.

The crystalline lens is as transparent as the purest crystal. Its consistency is that of hard jelly; but it is somewhat softer towards the edges. It is contained in a strong, transparent membrane, called the *arachnoides*, which is supported by radial fibres, bending inwards from the choroides :—these fibres are called the *ligamentum ciliare.* The place where this muscular ligament turns inward, is, around the outer part of the iris; and is called the *ciliare* circle; there also terminates the retina.

The appearance of the vitreous humour is that of melted glass; hence its name. It is not so hard as the crystalline, nor so soft as the aqueous humour.

Here, then, we have a complete apparatus for seeing in the form of a compact round ball; the shape of all others the best adapted for moving in a socket, which it does in every possible direction; and which is accomplished by muscles attached to its outer coat. For its preservation, it is placed in a concavity called the orbit, well lined with fat to form a soft bed for it to rest upon, and to facilitate its movements. The edges of this concavity are of solid bone; and project on all sides above the level of the eye, to guard it from accidents. The eyebrows protect it from substances that might slide down the forehead; and the eyelids cover it up while we are asleep; and while we are awake, being furnished with a liquor for the purpose, are continually washing, moistening, and rendering it transparent. To prevent the eyelids from falling into wrinkles, they are stiffened with a cartilaginous arch. Each eye is also furnished with two palisades of short hair,—the eye-lashes, that ward off flies, or such small objects as float in the air.

As to the eye's internal structure,—where the sight is perfect, the lens is so disposed, that the focal distance is immediately at the retina; and there is the inverted image painted and thence the sensation is conveyed to the brain. But, because we sometimes view objects with a great deal of light, and at other times with very little, there is a contrivance to remedy the inconvenience which might arise from this circumstance to the optic nerve. This consists of a double set of muscles placed in the iris. In the front of the iris is a hole filled with the aqueous humour, which humour easily gives way to any pressure. This hole, by the one set of muscles we can at pleasure enlarge, and by the other contract; and that so easily, that by habit we do it unconsciously. Should the light be too great, as when we look at the sun or a candle, we then contract the hole in the

iris, like the mouth of a purse, till not more of the pupil is seen than a part about the size of a small pin-head; and, on the contrary, should it be nearly dark, we enlarge the orifice when the pupil appears about the size of a pea; so that the number of rays admitted on both occasions approximate to an equality.

But utility is not all that Nature aims at in her works,—she is as fond of beauty as any of her admirers; and therefore she has painted the iris of the eye, by far the most conspicuous part of the body, with such a variety of colours, and with what an amateur would call effect, that no art can imitate. And this surrounding the black or very deep purple of the pupil, gives, when enlivened with intellect and sentiment, an indescribable expression to the whole; so that the eye is very truly stiled the mental index and the window of the soul.

When both the surfaces of a double convex lens are alike, the focal distance on each side is the same. The diameter of the eye-ball is only about three-quarters of an inch, and at this distance must the focus be. Had both sides of the crystalline lens been of the same convexity, the point at which we could have viewed objects the best would therefore have been at three-quarters of an inch from the eye—a very inconvenient distance. To obviate this difficulty, the outer convex is considerably flatter than the inner and half as broad again; so that by this simple contrivance, instead of seeing a very small object the best at the above distance, to the great annoyance of a very conspicuous feature, we can see the best at a distance of seven or eight inches.

By the assistance of the muscular ligament, called the ligamentum ciliare, we are enabled, though we do it unconsciously, to partially alter the convexity of the crystalline lens, as we look at objects near or at a distance. Nature, whose works always display the most consummate wisdom and unbounded benevolence of design, has a wonderful contrivance in this respect for the convenience of birds. It is necessary that they should, both for the purpose of seeking their prey and avoiding danger, be enabled to see objects at a great distance; consequently, there is a peculiarity in the structure of their eyes. It is found that they can flatten the crystalline lens, and thus see at a greater distance than any other animal. But this is not all. Were the eye stationary in this position, they would be totally blind at the distance of their beaks; and,

consequently, could not see small seeds and insects upon which most of them subsist. Therefore, they can also increase the convexity, so as to suit the focal distance exactly to the tip of their bills.

Defective sight generally arises, either from the rays uniting before they reach the retina, or not till they are past it. In the former case, the person is said to be near sighted; and the contrary, in the latter. Near sight is owing to too much fulness of the humours, causing too great convexity of the cornea or crystalline lens. Where this defect is found it is mostly in young persons. But in old age these humours pine, consequently the crystalline lens and cornea become flatter; and, therefore, people near sighted while young, will, in old age, have perfect vision, because the focal distance will then be at the retina. But in the eyes of old people, who enjoyed good sight when young, the focus is behind the retina;—hence their vision is indistinct.

Spectacles are lenses made to correct these defects. In the case of near sighted persons the eye is too strong; it can do too much, and therefore it is necessary to have a lens to weaken it, or give it more to do. Parallel rays, passing through a double concave lens, are made to diverge; consequently, when such diverging rays are made to pass through a double convex lens, as through the crystalline humour, the focal distance is increased; and thus are they made to reach the retina before they unite; and, therefore, to produce perfect vision. An aged person, with dim sight, always holds the thing he wishes to see at a great distance, that the rays may be the more converged when they arrive at the eye; and, consequently, sooner come to a focus behind the crystalline lens. He therefore needs a double convex to partially converge the rays, and thus to answer the purpose of holding objects at so great a distance; and yet, collect as many rays as when he holds them at the usual distance. As persons grow older, the convexity of the lens must be increased in the one case; and in the other, the concavity diminished.

Sometimes dimness of sight proceeds from want of transparency in the humours, or a defect in the optic nerve;—when the help of glasses is of no avail; and sometimes the loss of sight is caused by excess in the quantity of the vitreous humour,—and then, a small instrument, run through the front of the eye on

one side of the iris, will let out some of this humour, and remedy the defect:—the operation is called *couching*.)

There is no animal found with less than two eyes; but the greater part of insects have more than two. The spider and scorpion have eight. Some insects have more than a thousand eyes collected in two orbits. In a fly sixteen thousand eyes have been counted; in a beetle six thousand three hundred and sixty-two; and in a butter-fly sixty-four thousand six hundred and fifty.

The figure of the pupil, also, differs in different animals. In man it is circular; in the ox it is oval, the longer diameter being across the face; and in the cat it is oval, but the longer diameter is perpendicular. In such animals as seek their prey by night, the pupil is much larger, than in such as seek it by day; so that, they may collect more rays, and thus have a more lively impression on the retina. But each contrivance is always exactly adapted to the creature's peculiar way of life, and to the distinguishing of its food. The atheist may call all these evident contrivances in the eye, chance or appetency; but the christian reads in them, a luminous manifestation of that wisdom and benevolence, which pervade all the works of nature.

9. OPTICAL INSTRUMENTS.

Objects appear large or small according to the distance at which they are viewed. Thus, an object, at the distance of 100 yards, appears to be but half the size that it is when at half that distance; and no more than one-tenth as large as it appears to be when it is at the distance of only 10 yards: see Fig. 41. Hence, when we know the real size of any object we can judge of the distance by its apparent size; but in other cases, we are continually labouring under the deception caused by the distance of objects. If we look down a long street with a row of houses on each side, though the rows are parallel, they seem to come together at the bottom. Should we stand close to, or lay at the foot of a high wall, as the gable of a house, and look upwards, the wall, though perpendicular, seems to be hanging over us and to be falling. Sailors in the Pacific Ocean, on the western side of the highest Andes, even miles distant from the shore, still have the impression of these stupendously high mountains overhanging them. Looking across the sea, it appears to rise

into a ridge, and it gives the idea, when viewed from a distance, of a dark mountain: whereas, in reality it declines the contrary way, being a portion of a globe on the highest point of which we stand. The moon, also, appears larger than the sun; and will sometimes, as in an eclipse, even cover his disc; though, the one is comparatively a mere speck to the other.

Now as the object at 10 yards distance, subtends an angle at the eye ten times greater than it does at 100 yards; if, by any means, we can view the object, while at this last distance, under the same angle as when it is at only 10 yards, it will appear magnified ten times—or, as we sometimes express it, will be brought ten times nearer.—To produce a similar effect is the object of all microscopes and telescopes.

Microscopes.—The most simple microscope is made by boring a hole with a pin through a piece of black paper. Through this hole we can look at an object, suppose a grain of sand, by reason of all the rays except those that come from the object being excluded, at only an inch distance. Now, if with the naked eye we could not view it nearer than 8 inches, by being enabled to view it at only one inch, the diameter of the image on the retina will be eight times greater; consequently, the surface will be magnified 64 times, and the bulk 512.

The principle of the microscope is easily demonstrated from what was said on the description of the convex lens. The rays from a small object are divergent; consequently those from a grain of sand, at the distance of an inch, would diverge as from a focus; and the rays passing through the crystalline lens would be rendered parallel; and therefore no image could be depicted on the retina. But being viewed through the pin hole in the paper, only such rays will come through the hole as are parallel; but parallel rays passing through a double convex lens converge to a point called the focus, which point in the eye is at the retina.

There are *three* kinds of microscopes: the *single*, the *compound*, and the *solar*. But all act on the principle of presenting us with an image nearer the eye; and of excluding all the rays except those from the object.

The *single* microscope is the double convex lens; the object is placed at its focus, and the rays are thus made parallel; so that a much larger number enter the eye; and being parallel, are concentrated at the focus on the retina. The magnifying power is equal to the distance at which we view the object with

the naked eye, divided by the focal distance of the lens. Should the one be 7 inches, and the other only a quarter of an inch; then, the diameter will be magnified 28 times, and the surface 184.

The *compound* microscope (see Fig. 42) consists of two convex lenses: the one next the object, is called the object glass, and the other next the eye is the eye glass. The object *a b* is placed a little beyond the focal distance; and its magnified image *c d* at the opposite side is met by the focus of the eye glass: the eye being at the other focal point *e*. The rays therefore from each point will be parallel with each other till they arrive at the eye, when they will begin to converge by the refractive power of the humours; and as the image extends an angle, they will cross each other within the eye, and depict an inverted image B A on the retina. In this case, it is the image, and not the object, that is viewed by the eye. The magnifying power is in proportion, as the image is made larger than the object by the object glass, multiplied by the power obtained in the eye glass by our being enabled to view it at a less distance. There are frequently two eye glasses, when the object is less magnified, but more of it is seen.

In the *solar* microscope Fig. 43, the suns rays *s s* are reflected through a tube fixed in a window shutter, into a dark room. In this tube is a double convex lens, which converges the rays upon an object *c d* placed within the focal distance. The rays then, before they come to a focus and, consequently, while they are convergent, pass through another double convex lens *e f*; and the image is exhibited on a sheet of white paper. The rays being divergent, the image C D will be of any magnitude according to the distance of the paper from the lens; and so distinctly exhibited, that a person may draw its outlines on the back of the paper.

Some microscopes are fitted up with a concave mirror, so that the object, being placed near the focus of the reflected rays, is examined in a much greater quantity of light.

Telescopes.—Telescopes are of two kinds; *refracting* and *reflecting* telescopes. The most simple refracting telescope consists of an object glass, and one eye glass—both convex: the former being much broader and flatter than the latter. The design of the object glass is to produce a new image; and of the eye glass, to enable us to view it under an enlarged angle; the distance that the two glasses are placed from each other in the tube, is equal to the two focal distances. For instance, if with

the naked eye we see an object at the distance of 100 yards, under an angle of one degree, and the glass enable us to view it under an angle of 10 degrees, by producing an image at the focal distance of the eye glass; then it magnifies ten times, and produces the same effect on the retina as if we had advanced to within ten yards of the object. Unless the focal distance of the object glass be greater than the focal distance of the eye glass, the object will not be magnified. Should it be less, it will be diminished, as when we look through a telescope reversed; therefore, the magnifying power will depend upon the disproportion of the focal distances, and is found by dividing the one by the other. In the above case, where the magnifying power is 10, if the focal distance of the object glass be 10 inches, that of the eye-glass will be but one. Hence the power of telescopes does not depend more upon the length, than upon the convexity of the eye-glass.

But though this telescope, if long enough, may be made to magnify to any degree, yet the focal distances must bear some proportion to each other. An object glass, whose focal distance is 10 feet, will not admit of an eye-glass with a less focal distance than 2½ inches; and the telescope will magnify 48 times. An object glass of 100 feet focal distance, must have an eye-glass with more than 6 inches focal distance; the magnifying power is near 200. However, as this telescope with only two glasses, inverts the images with respect to the objects, it is only fit for viewing the heavenly bodies.

Some of the larger pocket telescopes contain five lenses; of these, three are eye-glasses, all of the same focal distance; one object glass, and the remaining lens is added merely to give the figure an upright position.

A great inconvenience at one time attended refracting telescopes, on account of the edge of the lenses, especially if they were large, or very convex, causing the prismatic colours. This was happily remedied by Dolland, who invented the *achromatic* lens, in which, by combining the plate and crown glass in the same lens, he counteracted each other's effects. Another contrivance is also made use of to remedy this defect. It consists of a plate fixed in the tube near one of the foci, with a small hole in the centre, through which the axes of all the lenses would pass; and, of course, the rays of light must go through it; the hole being small, the outside straggling rays of colour are cut off, and also absorbed by the plate being black-

ened. This circumscribes the image, and lessens the field of view; but it cannot be well dispensed with: and after all, by reason of the prismatic colours, refracting telescopes are on a limited scale.

GALILEO's telescope is a refractor; and consists of a double convex object glass, and a double concave eye glass; and the distance between them is equal to the difference of their focal distances. The telescope with which he discovered Jupiter's satellites only magnified twelve times. This glass has the most light of any of them; but by reason of the concave eye glass, some rays do not enter the eye; and therefore the image is rendered indistinct—consequently, the glass is only used for short distances. The common opera glass is one in miniature.

NEWTON's reflecting telescope consists of a concave mirror, a plane mirror, and a double convex lens. The concave mirror is placed at the lower end of the tube; and before the reflected rays unite at a focus, they fall upon the plane mirror placed at an angle of 45 degrees, which reflects them to the lens, or eye glass at the top; so that the observer looks down into the tube. The light being twice reflected, loses much of its intensity.

GREGORY's reflector has two concave mirrors, and two plano-convex lenses; and the observer uses it as a common pocket telescope. The larger mirror, which is disposed near the eye glass, has a round hole at its centre. At the front of this hole, but beyond the focal distance of the mirror, is placed the other mirror. The parallel rays, falling upon the larger mirror, are reflected back to the smaller; and back again through the hole of the larger to the lenses or eye glass placed behind it. The disadvantage arises from the loss in being twice reflected, and from a large portion of rays being lost on account of the hole in the centre of the larger mirror, or, the intervention of the smaller mirror between the larger and incidental rays.

Sir W. HERSCHEL's large telescope is the most simple of all. It has but a mirror and a lens. The mirror is placed at the bottom of the tube, and reflects the rays back to the object end, where they are united in a focus and farther condensed by the lens:—consequently the observer has his back to the object. The polished surface of the mirror is 48 inches diameter; the length of the tube 40 feet; and the focal distance of the mirror 39½ feet. The instrument magnifies about 6000 times; and the light, being only once reflected, has more intensity than that of either of the above. This instrument was completed in the year

Fig. 37.

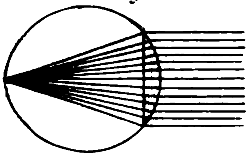


Fig. 38.

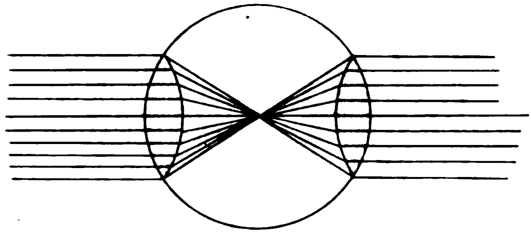
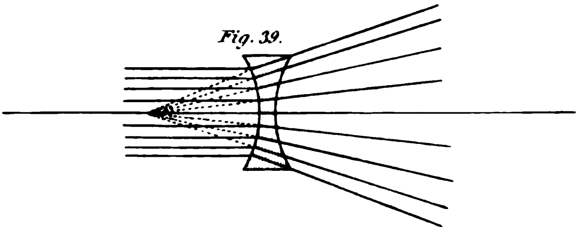


Fig. 39.



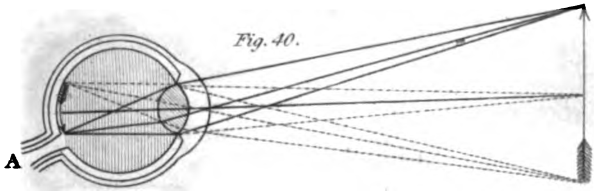


Fig. 40.

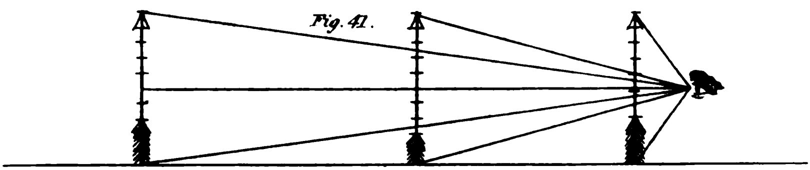


Fig. 41.

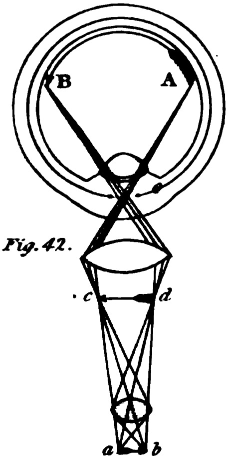


Fig. 42.

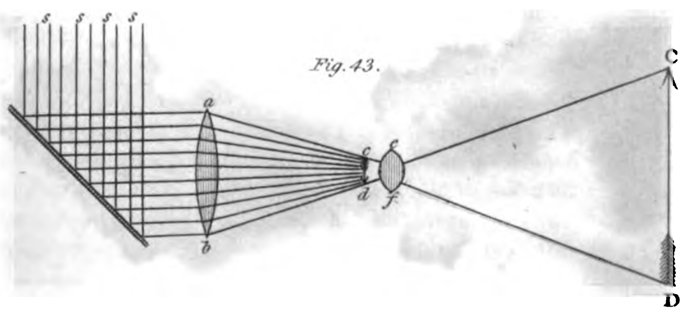


Fig. 43.

Fenner sc. Pater Noster Row London

1789, under the sole direction of the above truly great man, and is the most stupendous monument of the optical art hitherto erected.

The *Camera Obscura* consists of a lens fixed on one side of a box; on the opposite side is a plane mirror, disposed at an angle of 45 degrees, which reflects the rays to a square of rough glass placed as part of the lid of the box. These being disposed according to the focal distance of the lens, and placed in a dark room or tent of black cloth, so, that no light is admitted but through the lens,—the images of the objects, to which the lens is directed, are pourtrayed in miniature upon the rough glass. In this manner may the most beautiful scenes of nature be represented with a more faithful proportion of outline, and with more accuracy and delicacy of touch, than art can pretend to imitate, much less to equal. Sometimes this instrument is used for examining small pictures; which, being fixed in the place of the rough glass, are seen by the spectator looking through the lens, with all their beauties or blemishes greatly magnified. On a slight comparison it will be seen, that the camera obscura is an exact representation of the eye: the mirror acting the part of the retina, (See Fig. 40). Some opera glasses are constructed on the principle of the camera obscura; by the help of which the spectator is enabled to view an object sideways, or while he appears to be looking in another direction.

The *Magic Lantern* consists of two unequal convex lenses placed in a tube. The tube is so contrived, that little images, painted on glass or any transparent medium, may be slid sideways into it near the junction of the two foci. The end of the tube containing the larger lens is fixed in a lantern; and a candle is placed at the focal distance. A concave mirror is sometimes placed at the other side of the candle, which being in the focus, the rays are reflected parallel to the lens, and afford much more light to the apparatus. It must be used in a dark room; and the lantern must emit no light but through the tube, which, being directed to a white skreen, throws the magnified image thereon.

The *Phantasmagoria.*—Instead of opaque images painted on transparent slides, transparent images are sometimes fixed in opaque slides; or, the shape of an object is merely cut out in tin slides, when the rays passing through the hole, only a phantom of light of exactly the same shape as the hole, is

thrown upon a dark skreen or exhibited in the air. On the rapidity with which the slides can be changed, or one figure substituted for another, depends the perfection of this apparatus. It is generally used for the representation of ludicrous objects; but may be applied to the most serious and sublime subjects, even that of representing the motions of the heavenly bodies.

The *Multiplying Glass.*—Should a plano-convex lens have different facets ground at equal angles on the convex side, the eye at the focal distance on the plano side, looking through the lens at an object in the axis, will see it in the direction of every facet.

The *Telegraph.* This apparatus is contrived for making signals which may be read at a distance. It has six shutters, which can be moved with ropes like bell ropes; and which are marked a, b, c, d, e, f. It is capable of making 64 signals, representing the 24 letters of the alphabet; the 10 digits 1, 2, 3, &c. and various leading words. By means of a number of these placed in a line on eminences 10 or 12 miles asunder, with an observer and a good telescope stationed at the bottom of each, intelligence can be conveyed across a country at the rate of 100 miles in five minutes. Of course, they are of no use in wet or misty weather.

CHAP. IX.

Electro-Chemistry.

1. Chemistry and Alchemy. 2. Transformation of Matter. 3. The Elements. 4. Electricity. 5. Definite Proportion. 6. Combination Exemplified. 7. The Present State of the Science. 8. Uncombined Electricity. 9. The Electrifying Machine. 10. Galvanism.

1. CHEMISTRY AND ALCHEMY.

Chemistry is the science which teaches the investigation of matter, and describes its physical properties. It may be termed the key which unlocks the secrets of nature, enabling us to make her treasures all our own. It is, therefore, both on account of the wonders it displays, and its general utility in promoting all the conveniences and refinements of life, the most fascinating and interesting of all the sciences. In short, the universe may be considered as one vast alembic, wherein the whole mass of matter is elaborated by the two electricities; which, having, in obedience to the Almighty Fiat, already moulded part of it into spheres, are still under the guidance of Infinite Wisdom, poising and impelling these spheres in their orbits, and exerting a peculiar energy on all their component ingredients.

Mankind, having by long observation and experience, detected this energy, which they have named Chemical Affinity, can now dissolve, by bringing the two electricities together, the most dense and tenacious substances in nature. Hence they have been enabled to discover, that there are but a few distinct ingredients of which this world, or at least the tangible part of it, is composed. When this important truth first began to

be developed, philosophers supposed that even these ingredients might be still farther simplified, or, that all ponderable matter might consist of the self-same material. This gave rise to a very specious, but very erroneous idea; viz. that one substance was convertible into another:—hence the origin of the science called Alchemy, whose principal object was to transmute base metals into gold, and to discover a universal medicine that would confer immortality on the frail body of man.

This science seems to have originated with the Saracens, and was imported into this country by the crusaders; and such a rage immediately seized the philosophical part of the inhabitants of Western Europe, along with the revival of learning, that it became a nuisance to society, and a law was passed in England, in the reign of Henry IV., making it felony to attempt the transmutation of metals.* However the remedy was perhaps worse than the disease; for, though the science ruined some of its cultivators, and enabled others to thrive by their knavery in tricking and deluding the unwary, it nevertheless was the occasion of some useful discoveries which greatly conduced to the general good. Yet it was a real hindrance to sound philosophy; for, chemistry, or the true method of investigating nature, made no great progress till this delusive science was abandoned. Nor indeed was it likely, that a man should devote his attention to the examination of substances from which he had no prospect of immediate advantage; so long as he imagined that a secret was within his reach, which would instantly lay all the wealth and grandeur of the world at his feet; and confer upon himself an endless life for the enjoyment of it.

Sir Robert Boyle, being aware of the absurdity of the above law, got it repealed, yet it appears that he did not believe transmutation impossible. Indeed, to this present day, though practice renders it altogether improbable that it will ever be accomplished; yet, theory by no means declares it impossible. However in his day mankind generally considered the alchemists as professing an "art without principles, the beginning of which was deceit, the progress delusion, and the end poverty;"

* It is said that the motive which led to the passing of this law, was,—least the precious metals should be so multiplied as to lose their value and cease to answer the purposes of commerce; or, that the alchemists should by their wealth overturn the government.

hence the evil at that time only affected themselves. In his day chemistry was instituted upon rational principles, since which time it has made rapid advances. Among its most successful cultivators in Britain, are, besides himself, Dr. Priestly, Professor Black, Lord G. Cavendish, and Bishop Watson; but no one has made so many or such grand discoveries in this science as Sir H. Davy.

2. TRANSFORMATION OF MATTER.

Almost every substance we see is a composition of different ingredients, called the elementary principles; but by chemical operations, the mass may be dissolved and the ingredients separated:—this process is called *decomposition*.

The operation of collecting the homogeneous ingredients, of ascertaining the quantity of each kind, and of detecting the peculiar laws by which they are combined in the substance under examination, is called *analizing* or *analytical* investigation.

Sometimes when a substance has been examined analytically a chemist will examine or prove it by *synthesis*; that is, he will take all the ingredients, or equal quantities of the self-same kind, and compound them according to the law; and if he produce that substance,—it is said to be proved by analysis and synthesis, and the result is then admitted as a scientific truth.

When a chemist has analyzed a substance, he has then obtained two or more different ingredients; which, in the present state of the science, cannot be farther decomposed:—these he calls elements, principles, or simple substances. The particles composing them are called the original particles; which in some cases, as in most of the metals, he can obtain in a solid mass; but in others, only as gas, and sometimes only in combination with one of the other elements.

He can describe the aggregate mass of these original particles, but can give no account of their form or magnitude individually. The nearest approximation is to say something by way of illustration. Dr. Keill computed, that the magnitude of a particle of assafœtida flying off in odour, is no more than the 38 trillionth part of a cubic inch. And Leewenhoeck says, that there are more animals in the milt of a cod fish, than there are men on the whole earth; that a single grain of sand is larger than four million of those creatures; that each of them has limbs, joints, sinews, lungs, arteries and veins, as perfectly and

as distinctly formed as the largest animals, with a circulation of blood; and that he found by calculation, a particle of this blood to be as much smaller than a globe of one tenth of an inch diameter, as such a globe is smaller than the whole earth.

As small as these particles of blood or assafœtida may be, they are, notwithstanding, compounded of two or more elementary substances; nor do we suppose that they are composed of original particles, which differ in size and other circumstances from such of their own kind as constitute the general mass of matter, whether we take an elephant an oak or a mountain; and therefore when the student of nature is informed, that all chemical operations are effected by these original particles assuming a new arrangement, he will have some idea of what is meant.

From the inconceivable smallness of the particles of which matter is composed, we may easily imagine, that there may be combinations so subtile as to elude the most rigid scrutiny of all our senses, aided by all the artificial means we can use. But whatever form matter may assume, chemistry has taught us that it cannot be annihilated, nor can its elementary principles be changed:—for, however we may conceal or disguise any one element by combining it with others, it may again be separated without either loss of weight or any change of quality. It was said of old that the Almighty, when he made the world, weighed the mountains and measured out the waters,—and the exact quantity is here still. There may be less or more of water; but if less, the ingredients have only assumed another form. For the elements of water exist in almost every substance in nature, and form a material part in all plants; and, therefore, when these are decomposed, whether by fire or any other means, the water is at length restored, though mostly in such a state of rarefaction as to elude observation. It nevertheless ascends into the atmosphere and returns to the earth in rain; and the other parts of the decomposing substance, either, assume the gaseous form, blend with the atmospheric air, and are thence absorbed by the leaves, and become the food of other vegetables; or, the grosser parts mingle with the soil, and are thence taken up by the roots of plants, so that they die but to give birth to others, and something always gathers up the fragments that nothing is lost.

3. THE ELEMENTS.

THE ancient philosophers imagined that all matter might be reduced to four simple substances, viz. fire, air, earth and water. These they call their four elements, supposing them incapable of decomposition. But the moderns, guided by principles deduced from experiments, have found, that fire is a mere act of combination of the two electricities, or a certain play of chemical affinity; that air is a heterogeneous and decompoundable mass; that the many and various substances, they included under the general term earth, have all been reduced to homogeneous masses, or to what are at present considered as elements; and that water is a compound of the two elementary principles hydrogen and oxygen. The elements, therefore, instead of being only 4, are now found to include 51 simple or indecompoundable substances. Of these 40 are metals; and the remaining 11 are named as follows:—oxygen, chlorine, and iodine. Hydrogen, nitrogen or azote, boron, carbon, sulphur, phosphorus, fluorine, and selenium.

Chemistry knows of no such thing as lifeless matter. The most inert clod we see, contains an active inherent principle, that causes it, when presented to certain other substances, to assume a new form and display new qualities. Nor can a substance by any art be deprived of this principle; though in many cases, and always when a substance enters into combination or a closer union with an other substance, a certain proportion is liberated; and is known by the term caloric or light and heat.

But this principle, which is, as it were, the life of matter, is sometimes found uncombined or pervading the surfaces of different substances for which it shews a predilection:—it is then known by the term *electricity*.

There are two kinds of electricity, called the negative and the positive. The negative is the inherent principle of activity in oxygen, chlorine and iodine; and these are sometimes called the supporters of combustion. Nitrogen is supposed to be a compound substance; and displays affinities partaking of the nature of both, though its distinguishing characteristic, is, its neutrality. All the other substances, including the metals, are the storehouses of the positive electricity, and are called combustible substances; except fluorine, the nature of which is not satisfactorily ascertained.

4. ELECTRICITY.

To Sir H. Davy we are indebted for the discovery of the real nature of electricity; and such a discovery it is, that, when the prejudices of the present age shall have passed away, the name of Davy will be as renowned in chemistry as that of Newton is in astronomy. Previously to his decomposition of the alkalies, potas and soda, with the large galvanic apparatus of the Surry Institution, this science was but a mere register of some of the habitudes of the electric fluids, and was pursued without any theory or knowledge of their real nature. It was then (in England) generally supposed that there is but one electric fluid, which is that now called the positive; and that all bodies contained a certain portion of it, which was considered as their natural share. But when a body was charged with more than this specific quantity, it was then said to be positively electrified; and when it contained less, it was then considered as negatively affected:—hence the terms *positive* and *negative* electricity. The science therefore treated of only what we shall for the sake of distinction call *uncombined* electricity. See sec. 8.

But the discoveries of this illustrious philosopher prove, that there are two electric fluids; so that when a body was in such a state that they pronounced it negatively electrified, or as possessing less than its natural quantity it was in reality charged with the fluid called the negative. But this is the least part of the discovery. He has established the fact, that the electric fluids are identical with the cause of chemical affinity.* That one of them is inherent in the one class of the elements; and the other in the other class; and that whenever these elements charged with the opposite fluids, are, under certain circumstances brought together, chemical combination takes place; the original particles of the one uniting with those of the other;

* "This view of the possibility of the dependance of electrical and chemical action upon the same cause, has been much misrepresented. It has been supposed that the idea was entertained, that chemical changes were occasioned by electrical changes, than which nothing is farther from the hypothesis, which I have ventured to advance. They are conceived, on the contrary, to be distinct phenomena, but produced by the *same power*, acting in one case on masses, and in the other case on particles." See Elements of Chemical Philosophy, page 165, by Sir H. Davy, LL.D.

particle to particle forming a new substance with all its demonstrable properties distinct from either of the two. But this union is only effected by each parting with a certain definite proportion of the electric fluid; so that it is the violent tendency, which these two fluids have to unite, that is the cause of attraction. A portion of the electric principle always remains with the matter, (or it would perhaps be as proper to say, that matter and the electric fluids are of indivisible essence), which retaining its attraction for the other fluid, constitute the cause of the original particles combining so very closely. The definite proportions of each fluid, thus given out, by combining, form caloric. Should the new substance have a great capacity for caloric, it becomes latent; if not, it escapes as heat. So that fire, or combustion is neither more nor less than an example of chemical combination. It is an established law that when two substances combine, they condense; often passing from a gaseous to a liquid state, or from a liquid to a solid. Heat is likewise invariably produced; though sometimes solids combine and form liquids, when cold is the result:—the liquid requiring more caloric for its fluidity than the combination generates.

Electricity, then, existing as the cause of chemical affinity, is inherent in all substances; and is as much an essential ingredient as any of the ponderable material:—for this reason we shall call it combined electricity. Hence, we have two kinds of electricity; the *positive* and the *negative;* and they exist in two states, *combined* and *uncombined,* and perform very different offices in the economy of nature. Combined electricity is the cause of chemical affinity, as it relates to the use that man makes of it in common culinary purposes and chemical operations. It is, besides, the cause of all the natural changes in the mineral, vegetable, and animal kingdoms; and is also what gives motion to the heavenly bodies. Uncombined electricity is the cause of thunder and lightning, earthquakes, hurricanes, many of the winds, with a variety of minor phenomena, all of which will be explained in the following pages.

5. DEFINITE PROPORTION.

THE two electric fluids seem always to join in unvaried proportions to form caloric; but as their presence adds nothing to the weight of any body, and as we cannot confine them, so as to ascertain their quantity by measure, we have no means of as-

certaining what the calorific proportion is. However, this invariable proportion is a very important law in chemistry from which we infer, that equal quantities of each of the elementary substances are always joined with the same quantity of its respective electric fluid, providing they are either uncombined or in the same combination; and that equal quantities by weight of the different elements, have very different quantities of the respective inherent electric fluid. Thus: oxygen and chlorine are both vehicles of the negative electric fluid, but if we take equal weights, oxygen will combine with or saturate above four times as much of one of the other simple substances, containing the positive fluid, as chlorine will. And hydrogen will saturate more than double the quantity of oxygen that carbon will; and carbon more than any of the rest. Hence, wherever chemical combination takes place, certain definite proportions of the elements unite; nor can they by any means be made to unite in any other proportion. And when we have a compound substance knowing the weight and the component elements, we can always determine the exact quantity of each. It is the same both in simple and compound substances; so that when different ingredients, whether simple or compound, are to be united, a chemist knows what portion of each is necessary to form any quantity of the new substance. This law is now so well known, that numbers, according to the following table, are made use of to represent the proportions in which each element will unite with the other elements possessing the opposite electricity.

Oxygen	15	Zinc	66	Copper	120
Chlorine	67	Potassium	75	Barium	130
Hydrogen	1·	Sodium	88	Bismuth	135
Carbon	11·6	Arsenic	99	Antimony	170
Phosphorus	20·	Iron	103	Silver	205
Nitrogen	26·	Tin	110	Mercury	380
Sulphur	30·	Nickel	111	Lead	398

To exemplify the above table;—each number is called a proportion. Should we wish to combine oxygen with any of the other, they will only combine, either according to these proportions, multiples, or fractional parts of them. Suppose the proportion representing oxygen is 15 lbs.; then, that of hydrogen will be 1 lb. Now one proportion of oxygen combines with two of hydrogen; or 2lbs. weight of hydrogen gas contains, or will part with as much positive electricity as requires for the

formation of caloric, the negative electricity contained in, or is separable from 15lbs. of oxygen gas. Therefore, should the two gases come together in this proportion, and be strongly compressed, fired, or have an electric spark passed through them, they will combine. The two electricities will form caloric, which is seen in a flash of fire, and the two ponderable elements condense into *water;* so that, every 17lbs. of water contain 15lbs. of oxygen and 2lbs. of hydrogen.

We consider, then, the above mixture as containing the largest quantity of the electric fluids, with the least quantity of ponderable matter; and the two fluids as being in the calorific proportion: consequently, having a bladder filled with it, should a little be permitted to escape through a very small orifice, upon the flame of a lamp or piece of ignited charcoal, it will produce the most intense heat known. This apparatus is called the *Blowpipe.* Though to prevent accidents from explosion in chemical experiments, a somewhat different contrivance is made use of; such as having each gass in a separate bladder, or mixed in the proportion of 2lbs. oxygen to 1lb. hydrogen, the other oxygen being obtained from the atmosphere; and in all cases, except by experienced chemists, it is advisable for the sake of preventing accidents, to use bladders.

Should the two gases be mixed together in any other proportion than the aqueous, they either utterly refuse to combine, or if they do combine, it is only according to the above proportion; and the excess, on which ever side, remains as gas.

But although oxygen has only one combination with hydrogen, it has several with some of the other simple substances. That is, a proportion of each will combine under certain circumstances and form one substance; again, that substance under certain other circumstances will combine with another portion of oxygen, but it will be either the same proportion, a multiple of it, or a fractional part. Thus: oxygen has two combinations with carbon. The first, is one oxygen to one carbon; which substance is called carbonic oxide. The second, two oxygen to one carbon, which is carbonic acid; so that with 11·6lbs. of carbon we can obtain 26·6lbs. of the former substance, and 41·6lbs. of the latter.

With lead oxygen has three combinations, as follows:—

Yel. oxide,	2 oxygen	to 1 lead;	or 30lbs. oxygen	to 398lbs. lead.
Red do.	3 do.	to 1 do.	or 45lbs. do.	to 398lbs. do.
Puce do.	4 do.	to 1 do.	or 60lbs. do.	to 398lbs. do.

The numbers representing the compounds are found by adding each number of the bases to that of the oxygen. Thus: water consists of 1 oxygen or 15, and 2 hydrogen, making 17 the number in which water combines. Nor will it combine in any other quantity than 17, or some multiple of it as 34, 51, 68, &c. The number in which potas combines is 90:—because potassium and oxygen each combine in one proportion for its formation; that is, 15 oxygen and 75 potassium are equal to 90. "A great part of the phenomena of chemistry" says Sir H. Davy "may be submitted to calculation; and there is great reason to believe, that at no very distant period, the whole science will be capable of elucidation by mathematical principles."

It was said by the philosophers of old, respecting the rising of water in the common pump, that nature disdained a vacuum: how much more reason have we to say, that she disdains to work without the strictest, even the most correct mathematical rules; and that she most sedulously guards against the very possibility of her productions being either crude or monstrous!

6. COMBINATION EXEMPLIFIED.

Chemists enumerate three modes of combination as taking place among compound substances; which are distinguished by the terms, simple, compound, and disposing attraction.

Simple attraction, is, when two substances unite merely by their mutual affinity; as when a little nitric acid (aqua-fortis) is added to muriate of soda, (common table salt), the nitric acid will unite with the soda; and, if heat be added, the muriatic acid will evaporate, and nitrate of soda will remain.

Compound affinity, is, when two or more compound substances will mutually decompose each other, and form two or more new compounds; as when nitric acid, sulphate of ammonia, and nitrate of potas are added together, two new substances viz. sulphate of potas and nitrate of ammonia, are formed. When nitrate of lime and sulphate of magnesia, (Epsom salts), are dissolved in water and mixed together, the lime will quit the nitric acid to unite with the sulphuric acid, and the magnesia will leave the sulphuric acid to join with the nitric acid; the nitrate of magnesia will remain in solution, but the sulphate of lime will be precipitated as a white powder.

Disposing attraction, is, when two substances will not combine till a third be added: thus, should a little concentrated

sulphuric acid be poured upon iron, no action will ensue; but if a little water be added, a chemical combination takes place, and sulphate of iron (copperas) is formed.

Besides these, elective attraction is sometimes spoken of; as when one substance will unite with another in preference to certain others that may be presented at the same time, for which it has also an affinity. If a few particles of common table salt be put into a glass of water, they will dissolve; and the water, having a strong affinity for the salt, will blend it regularly throughout its mass—but should a little alcohol be added for which water has a greater affinity, the water will quit the salt to combine with the alcohol. The salt is now thrown down to the bottom of the glass; and in this manner may the ingredients of sea water be separated, and the composition of a variety of substances ascertained:— the process is called precipitation.

The excess of attractive power, that destroys the combination, is called the divellent power; and this kind of affinity is sometimes distinguished by the term, divellent.

All these modes of combination, in compound substances, are nothing more than this, viz. in the first combinations the elements had not parted with the whole of the electric fluids, that they are capable of parting with; and every fresh substance that is presented, containing the opposite fluid, will extract a portion from them; so that, with some substances, we may go on step by step till we arrive at a combination that no known substance will detach.—For instance, the metallic oxides will detach sulphuric acid from water: alumina will detach it from the metallic oxides; and ammonia again will detach it from alumina, magnesia from ammonia, then lime, soda, potas, strontites, and barytes will all successively detach each other; so that, at last we have sulphate of barytes.

The calorific proportion in this process may be thus stated. Sulphuric acid is composed of oxygen and sulphur, and therefore contains a portion of both the electric fluids; also, the water, and all the other substances, are compounded of the negative and positive elements; and in like manner contain a portion of each fluid. Now suppose, the sulphuric acid, before it combines with the water, contains 10 doses of the electric fluids; the water and all the other substances must likewise be supposed to contain 10 doses, each. When the sulphuric acid and water combine, they may be supposed to each lose one dose, which consequently form one portion of caloric. that

escapes. But when the acid is detached from the water, by the metallic oxide, the water is restored as water; and will require its one dose of electric fluids back again. In this case we must either suppose it supplied from the caloric of the new combination; or what is more likely, that the oxide parts with two doses, one of which is taken up by the water, and the other combines with one dose from the sulphuric acid to form another portion of caloric. The alumina will therefore part with three doses; and lastly the barytes with ten, nine of which will unite with strontites, and one with the last disposable dose of the acid for caloric. Should pure sulphuric acid and barytes be originally combined, the whole of the ten doses of each will form caloric; whereas, in the above case, there was only one dose; the proportion of the caloric in the two cases would therefore, be as ten to one; hence, the combination of simple substances generally produces a much higher temperature than the union of compounds.

As caloric is produced by all these combinations, its presence must have a very material effect: consequently we find that a certain degree of heat hastens all combinations. In short some substances, that have the greatest affinity for oxygen, as carbon, will not combine in the smallest degree without a very high temperature; so that, charcoal and even common pit coal, composed of hydrogen and carbon, will continue thousands of years exposed to the air without alteration. But as soon as they are heated to a temperature of 800 degrees, they unite most rapidly, as our common coal fires daily prove.

But, on the contrary, all compound substances may be decomposed by heat. For when the concentrated caloric is greater than that produced by the combination, attraction is overcome, and is made obedient to the repulsive laws of caloric—each element combining with its full quantity of inherent electric fluid. For instance, oxygen gas contained in the atmospheric air, has no effect upon mercury till it is heated to 600 degrees, when they combine and form red oxide of mercury. Again, if this red oxide be submitted to a temperature of 1000 degrees, the oxygen is dispersed as gas, and the mercury is restored to its pure metallic state. See COMBUSTION.

7. THE PRESENT STATE OF THE SCIENCE.

Though chemistry may justly boast of its late very rapid progress, it by no means pretends to have arrived at its ultimatum. Every new grade of improvement but shows that a great deal more is yet to be done. With respect to what are now called the simple substances, it is far from affirming that they are in reality such; but only that they must be considered as such till some new mode is discovered of farther decomposing them. In short, there are only two that can be properly looked upon as partaking of an elementary nature, viz. hydrogen and oxygen. Indeed there is sufficient reason for considering all the rest as compound substances.

An element is such a substance as is combined with but one electric fluid; and since the nature of each fluid is highly repulsive of itself, the particles of that substance when obtained alone must partake of the same nature, and be repulsive. Now hydrogen and oxygen exactly answer to this description, for when obtained alone they are as gas; that is, their particles will not come near each other, but have a continual tendency to disperse;—hence the elasticity of gaseous bodies as exemplified in the expansive force of atmospheric air. But most of the other substances, at present called simple, instead of their particles being repulsive at common temperatures, are found to constitute the most dense and tenacious of all bodies; as diamond, which is supposed to be pure carbon, and gold and platina among the metals.

Now as hydrogen enters into combination in quantity very much smaller than any other substance; and its particles are highly repulsive of each other, so much so, that its gas weighs a great deal less than any other gaseous or known substance, even 12 or 13 times less than oxygen gas, it has the first claim to be considered as an elementary substance. Sir. H. Davy says, there is a probability that this element, combined in different proportions with some unknown ponderable base, may constitute all the other solid substances which we consider as the storehouse of the positive electricity. On this hypothesis, those metals which are the most inflammable, that is, the most inclined to combine with oxygen, and do combine with the greatest quantity, must have the greatest proportion of hydrogen to the unknown base; so that the hydrogen will be the least attracted by, or less closely united with that base.

It also will have parted with fewer proportions of the inherent electric fluid; and its particles will retain the more of their repulsive nature, and will not be so near to each other in the mass, (for philosophy does not admit of the absolute contact of particles in any mass), consequently such metals must have the least specific gravity, which we accordingly find to be the case. On the contrary, platina, which has the greatest specific gravity of all the metals, and on this hypothesis must contain the least hydrogen—has of all the metals the greatest affinty for that substance. This may be proved by inclosing a little of the metal reduced to a very fine powder, and exposed to a stream of hydrogen gas, mixed with atmospheric air, in a tube, when it becomes intensely hot, and exhibits a most violent chemical action.

The probable proportions in which this unknown base and hydrogen may exist, he states as follows.

Nitrogen	16	unknown	base	10	hodrogen
Charcoal	7·4	do.	do.	4	do.
Phosphorus	16	-	-	4	-
Sulphur	24	-	-	6	-
Potassium	69	-	-	6	-
Sodium	82	-	-	6	-
Tin	106	-	-	4	-
Silver	203	-	-	2	-

On the same principle, he supposes chlorine to be a compound of four parts oxygen, to one of an unknown base:—though probability is less in its favour than in that of the above.

As to this unknown base of the inflammable substances it must be considered as a vehicle of the negative electric fluid; but whether there is but one or more no analogy, perhaps, can warrant us to hazard an opinion; so that, what the real number of elementary substances may be, chemistry is as far from knowing as ever. "Matter" says this illustrious philosopher "may ultimately be found the same in essence, differing only in the arrangement of its particles: or, two or three simple substances may produce all the varieties of compound bodies." But should all matter ultimately be found the same material, "a speculation sanctioned by the authority of Hooke, Newton, and Boscovich," united with different portions of the two inherent electric fluids, the science of chemistry is at present established on such principles, that these farther advances would make no material

alteration in it. The definite proportions would still remain the same; and the only change would be, those substances, which are now considered primary elements would then be but secondaries. "The result of our operations must, therefore, be considered as offering, at best, approximations only to the true knowledge of things, and should never be exalted as a standard to estimate the resources of nature".

However these things may ultimately prove, a consideration of the subject enables us to behold the infinitude of that skill displayed in the works of nature; and leads us to contemplate the consummate wisdom evinced in each contrivance. If we recollect the few materials made use of to build the stately and beautiful fabric of the creation, and the accuracy with which they are combined in each production; and, then, turn our eyes to the most perfect or stupendous works performed by the most successful efforts of man,—the bare idea imparted by the contrast, tends to annihilate every proud imagination, and to divest our minds of all self-conceit, even to the simplicity of a child; rather than to make us dare to raise our scrutinizing thoughts to the sanctuary of this adorable skill and power.

8. UNCOMBINED ELECTRICITY.

As the two electric fluids are thus discharged from their respective elements for the formation of caloric, it would seem, that the caloric, being dispersed, is again decomposed. Settling upon contiguous bodies that are unequally compounded of the different electric elements, the positive fluid rests upon the substances, that contain the most oxygen, and the negative upon the other. Many substances, especiallv sulphur, while cooling, exhibit electric phenomena; and some, on the contrary, while heating. There is a stone found in the British primary mountains called the tourmaline, crystallized by nature frequently in a nine sided prism, terminated by a six sided and a three sided pyramid,—which on being gently heated, becomes electrical: —the six sided pyramid end being positive, and the other negative. But while it is cooling, its charges are reversed. Under these circumstances, when the fluids accumulate so as to overcharge the stone, they combine in shocks; and if the stone be large, each shock is seen at stated intervals in flashes of light running over the surface. There are several other minerals that exhibit nearly the same phenomena. See Mineralogy, Chap. XII.

The electric fluids may be exhibited by rubbing a stick of sealing-wax smartly upon the coat-sleeve, or any piece of woollen, when the wax becomes charged with the negative and the woollen with the positive; which may be known by their attracting bits of thread, paper, gold-leaf, or any dust that is near. But if a glass tube be so rubbed, the woollen will be charged with the negative, and the glass with the positive. In the first case, the wax has more of the positive elements than the woollen, and it therefore attracts the negative fluid; and, in the second case, the woollen contains more of the positive, and it consequently attracts the negative, while the glass attracts the positive. Owing to this circumstance the positive fluid is sometimes called the *vitreous;* and the negative the *resinous.*

When two metals, as silver and zinc, the one having a slight affinity for oxygen and the other a violent one, are in contact, they exhibit no signs of electricity; but when separated, the silver is positively electrified and the zinc is negatively;—unless the zinc be coated with oxide, and then the charges are reversed.

But however a substance may be charged, it is found to pervade the surface only; and as caloric is always made up of unvarying proportions of the fluids; so whatever quantity of the one fluid we have around the surface of any body, the corresponding proportion of the other fluid is sure, whether we will or not, to be in the nearest adjoining surface; and this is an invariable rule whether the fluids are excited by art or nature. According to the composition and intimacy in the combinations, or the arrangement of the original particles in a substance, the electric fluids will pervade their surfaces or otherwise:—hence, when some substances are touched with a charged body, their surfaces are regularly charged throughout, while others remain only charged on the spot where they are touched. The former substances are therefore called *conductors,* because they will transmit the electric fluids from one substance to another; while the latter, which will not do so, are called *non-conductors.* The human body is a remarkable instance of the former; and whilst living permits the fluid to pass through it; but if all remains of vitality are gone, electricity then only pervades its surface. A pane of glass, touched on one side with a charged substance, will be charged at that side; but will at the same instant become charged at the

opposite side with the other fluid; and in this case, they cannot come together, because glass is a non-conductor; but if a communication is formed between the two sides, by a piece of wire, the two fluids instantly rush together. The metals are all conductors, though not all equally good. Among the non-conductors, are, in the first place, glass, wax, and resinous substances; silk, feathers, wool, hair, and atmospheric air. Iron is said to conduct 400 million times better than water, sea-water 100 times better than distilled water, and water saturated with salt 720 times better.

A conductor supported by a non-conductor is said to be *insulated*; and in such a case, when charged, will retain the electric fluid for a considerable time—with great care even for 24 hours. Along perfect conductors the electric fluid will pass any distance, and that without any perceptible time. Walker in his "Elements of Experimental Philosophy," speaks of having conducted electricity, by means of a wire suspended on a park wall, nine miles; and says that the two fluids joined each other, though one of them travelled all this space, as instantaneously, as if the conjunction had been made along a wire of a few inches. He also electrified two regiments of soldiers consisting of 1800 men, who all apparently received the shock at the same instant. Nor is the fluid diminished in its passage; for Bishop Watson, with a wire in the water, conducted electricity to the opposite side of the Thames and back again; and on the junction of the two fluids fired spirits of wine. Gunpowder has also been fired, after the fluid had passed through 20 persons having hold of each other's wetted hands. Bringing the two fluids together, by means of a wire or any other conductor forming a communication between the two charged surfaces, is called "completing the electric circuit;" and wherever the two fluids unite they produce caloric and a shock. The caloric, should the charge be small, is a mere spark; and the shock is produced by its action on the air, or on the human body by its effects on the nerves and muscles.

9. THE ELECTRIFYING MACHINE.

THE electrifying machine is an apparatus for exciting the electric fluids by friction. It consists of a revolving glass cylinder, insulated by the fixing of its pivots or axis, or by being supported on glass pillars. On the top of this cylinder is a

rubber or cushion, coated on the side next the glass with tin foil or an amalgam of zinc and mercury. The cushion is supported on the top of a glass pillar for the purpose of insulating it; and made to press, sometimes with a spring, upon the revolving cylinder. On one end of the axis of the cylinder is sometimes a small wheel, which communicates by a cord of silk or catgut with a larger wheel, attached to the handle. This band may answer a double purpose; for, besides its acting as a multiplying wheel, so that the cylinder revolves many times for the handle once, it is a non-conductor, (should the axis not be insulated,) between the cylinder and the person turning the handle.

By the friction or pressure thereby occasioned, the latent caloric is put in motion; and particles of oxygen gas are pressed between the rubber and the cylinder, so that a slight oxydation of the amalgam takes place. Though Sir H. Davy does not suppose that the action of the machine depends upon the oxidation of the amalgam, for it acts equally in vacuo, in hydrogen gas, and better in carbonic acid than in atmospheric air. It must therefore depend upon the caloric of the surrounding bodies: the machine will only act in a warm, dry atmosphere.

However this may be, the electric fluids are excited; and, under this peculiar combination of circumstances, do not immediately unite, but the positive charges the glass cylinder and the negative the cushion, till by their superabundance they are compelled to combine and form caloric; but to prevent this, they are, by properly disposed conductors, withdrawn. The negative is conducted away by a chain attached to the cushion, while the other end lies upon the ground or table communicating with it; but to remove the positive from the cylinder requires a little more contrivance. For this purpose, a metallic cylinder is placed at right angles to the glass cylinder, supported on glass pillars. At the end of the cylinder are a few spikes of wire, an inch or so in length, which reach within half an inch of the glass cylinder. And to the cushion is attached a square piece of varnished silk, that rests upon the glass cylinder, and reaches to within about half an inch of the place to which the metallic points are opposite. When therefore the machine is in action, the positive fluid is drawn off by these points, till the metallic cylinder, called the prime conductor, is charged.

To complete the apparatus, a chain is attached to the prime conductor. Each chain has also a small metallic rod, with a

hook at one end to fasten the chain, and a knob at the other; and to each rod is fixed a glass handle, so that the operator may not receive the shock himself. Some machines are fitted up with a prime conductor for the negative fluid; or when the negative fluid is used, the chain of the positive communicates with the earth.

If, while a person holds a chain in each hand, the machine be put in motion, the circuit will be completed in his body. He will feel a peculiar sensation, but no shock; because the streams come regularly, and also combine as they meet in his body. But if he hold the positive chain, while standing on a stool with glass feet, he becomes electrified. The hairs of his head stand upright; for being charged with the same fluid as his body, they are repelled, and also repel each other. While in this situation, should he be touched with the knob of the negative chain, he will instantly feel a shock at the part or limb where he is touched: or, the knob being held at a distance, sparks may be drawn from any part of his body; that is, the two fluids will meet between him and the knob, and form caloric, which appears in sparks. It will be the same, if the end of the negative chain lie upon the ground; for, a person standing on the floor, and touching the insulated person, equally completes the electric circuit. So that a person standing on the floor and turning the machine with one hand, at the same time holding the knuckles of the other hand near the prime conductor, will see, as it were, sparks come into his hand, and feel the sensation of a pin pricking him. In this case, the negative fluid passes from the chain to the floor, then, to the person, and at the knuckles meets the positive where the spark is seen or pricking sensation felt.

Two bodies charged with the same electricity repel each other; but are attracted if charged with the opposite fluids. On this principle, little images made of pasteboard, or pith of the elder have been made to dance up and down between two metallic plates placed a few inches apart. The under plate not being insulated, and the negative chain communicating with the floor, becomes negatively charged. Directly over it, at the distance of a few inches, is suspended by non-conductors the other plate, which communicates with the machine by the positive chain. The images placed on the lower plate, while the machine is in motion, become charged with the negative fluid; and because bodies charged with the same fluid repel each other, and those charged with the opposite attract each other, the images are

repelled from the lower and are attracted to the upper plate, where they discharge their load of the negative, which uniting with a definite proportion of the positive, forms caloric. They then take a charge of the positive, and for the same reason are repelled; and are attracted to the negative plate, where another portion of caloric is formed; and they are again repelled with a charge of the negative. Thus; if a supply to the plates be kept up from the machine, they continue to dance: the greater the charge, the quicker the motion.

The *Leyden Battery* consists of a number of glass jars, coated with tin foil or the above amalgam inside and out to within a few inches of the top, and placed so, that a wire may communicate with the inside of each without touching the outside. These wires are all attached to a rod, which being joined to the positive chain, forms a communication with the inside of the jars and prime conductor. The battery being insulated, and the negative chain attached to it, when the machine is put in motion, both inside and out are equally charged: one with the positive fluid and the other with the negative; but by reason of the top of each jar not being coated, they will not come together.

Almost any quantity may be thus collected; and for operating with it, the object is placed at a convenient distance completely insulated; and having two chains, one communicating with the inside of the jar and the other with the outside, it is first touched with the one, when it becomes charged but receives no shock till touched with the other, when, if the charge be great, the blow is tremendous. The caloric does not seem large in quantity, but its intensity is irresistible. An ox has been struck dead, diamond evaporated, and substances, previously deemed infusible, have been melted like wax.

10. GALVANISM.

GALVANISM is a mode of exciting the electric fluids by oxidizing two metals in contact, that possess different attractions for oxygen. The peculiar effect, which electricity has upon the nerves and muscles of animals, was the circumstance that gave rise to this branch of the science; and it has therefore sometimes been called *animal* electricity.

A philosopher named Galvani was its first cultivator. While he was dissecting a recently killed frog for the purpose of investigating the cause of nervous irritability, he observed, that when

the two instruments he was using, being of different metals, were so disposed that the one touched the nerve and the other a muscle of the same limb, and at the same time came in contact with each other, a spasmodic motion of that limb ensued. He imagined the cause to be in the frog and not in the metals; and, not suspecting it to be an electric phenomenon, announced to the world that he had discovered a new power, which was called *Galvanism* in honour of himself.

But another philosopher, named Volta, soon identified it with electricity, which he shewed was excited by the action of the animal moisture upon the metals; and that whenever the nerves and muscles of a body recently dead are touched at the same time with the two electric fluids, the nerves with the positive, convulsions of the limbs ensue symptomatic of returning life. He invented the galvanic pile and trough, which are consequently sometimes called the *Voltaic* apparatus.

An experiment in galvanism may be easily made, by placing a piece of zinc or even a bright key upon the tongue, and a piece of silver beneath it, both moistened with the saliva. When the other ends are brought in contact beyond the tip of the tongue, a slight shock and a peculiar sensation are felt. If zinc be used, and the experiment be made in the dark, a faint flash of light will be seen, and the taste will resemble that of diluted ammonia. Porter is said to drink best out of pewter. Now pewter is a mixture of metals, and the porter acts as an acid that promotes oxidation. The two electric fluids are therefore excited; and when a person drinks, the circuit is completed at his mouth, and the effect on the nerves, at the seat of the sense of taste, gives a new and peculiar flavour to the porter. By the effects of galvanism, metals soldered with other metals, nails in the sheathing of ships, and all metals under like circumstances, especially if exposed to moisture, soon corrode at the place of contact.

The uncombined electric fluids have a great effect on chemical affinity. Two substances will much more readily combine, when the one containing the most of the positive elements is charged positively; and they are, on the contrary, much slower in combining, or utterly refuse to combine, when it is charged negatively: or when the substance containing the most negative elements is charged with the positive fluid. A slow combination is continually going on between the copper, with which ships are sheathed, and the saline contents of sea water:—

chlorine, a chief ingredient in these salts, and which is a negative element, having a great affinity for copper a positive elementary substance. But Sir H. Davy discovered that a very small surface of tin, or any other metal which has a great affinity for oxygen, placed any where in contact with a large surface of copper, renders it negatively electrical, so that sea water has no action upon it.

The difference between common electric phenomena and the galvanic may perhaps be thus stated. The former depend upon the surrounding active caloric, while the latter are developed from the inherent electric fluids of the decomposing or combining materials. When two metals are brought in contact, and are immediately separated, they are electric: this arises from the decomposition of the active caloric. But should they be touched by an acid, or a saline ingredient as animal moisture, while in contact, the one that has the greatest affinity for oxygen becomes oxided; that is the electric fluids separate from their respective elements, the positive from the metal and the negative from the oxygen, and in the calorific proportion, so that under common circumstances they form caloric. Now these fluids under the galvanic arrangement are either withdrawn before they combine, or the caloric is immediately decomposed and the fluids are separated by the contiguous positive and negative materials. For the amalgam of the electrifying machine and the predominance of the negative elements that compose the glass, bear a great similarity to the contiguous metals and acid of the galvanic apparatus. The chief difference in the phenomena may, therefore, arise from the sources of the fluids: in the electrifying machine they are obtained from the caloric existing as the temperature of the materials, and the supply is much more irregular; in the galvanic apparatus they are derived from the inherent electric fluids of the materials, viz. of the metals and acid; and as the oxidizing process is very slow, but uniform, and no more of the electric fluids are developed than the combination affords, so the galvanic apparatus affords a regular stream of the two fluids, without being subject to violent discharges in shocks, as is the case when the fluids are excited by the machine. A Leyden Battery may be charged with the galvanic apparatus, but not easily.

The galvanic *pile* is made with any number of plates of two metals, that possess different attractions for oxygen. They are placed in pairs one upon another; and between each pair is in-

serted a piece of woollen cloth, steeped in a solution of sal-ammoniac and water; or a mixture of nitric and sulphuric acids and water—the proportion of each acid being one sixtieth part of the water. The whole is supported by glass pillars. There is no determined order of placing them with respect to which shall be uppermost. But if that which has the greatest affinity for oxygen be fixed on, then it must be uppermost in every pair; and the pile must commence with a single plate of that which has the least affinity at the bottom, and terminate with a single plate of the other at the top: and between each pair, as well as adjoining each single plate, must be a piece of cloth. Being thus disposed, the top of the pile becomes immediately charged with the negative fluid, and the bottom with the positive.

But the galvanic *trough* is now generally preferred. There are several variations in its construction, but that of the Surry Institution is the most famous. It consists of 2,000 double plates soldered together, placed in as many cells of a porcelain trough. The plates fit closely into each cell, so as to make a water tight partition; and the intervening spaces are filled with the above mixture of acids and water. But as the plates are soon covered with oxide, they are so contrived as to be readily taken out and wiped. The area of each plate is 32 square inches, so that 128,000 square inches of surface are exposed to the acids. In some troughs the plates are not soldered, but merely joined by a metallic clasp, and thus a double portion of surface is acted on. A wire of platina is attached to each end of the trough; and when the other ends of the wires are brought within three or four inches of each other, a discharge is made of each fluid through the air, producing a most brilliant ascending arch of light, broad, and of a conical form in the middle. When a substance is brought into this arch, it instantly becomes ignited. Platina melts as readily as wax in a candle. Quartz, sapphire, magnesia, and lime are fused; diamond is evaporated; and Icelandic spar (once considered the most infusible of all substances) when moistened, is acted upon; indeed nothing can resist its attack. Its operations are slow, but the results are certain; and sooner or later, by means of it, bodies are reduced to simpler forms of matter.

If the two ends of the wires are placed in water, it is decomposed; and oxygen gas is evolved from the positive wire and hydrogen from the negative. If acids or salts or any other

compound substances are acted upon, the negative elements are evolved from the positive wire; and the positive from the negative. It was with this apparatus that Sir H. Davy decomposed the earths and alkalies &c., and made the great discoveries which will immortalize his name.

CHAP. X.

The Supporters of Combustion.

1. Remarks. 2. Oxygen. 3. Chlorine. 4. Iodine. 5. Oxides. 6. The Alkalies. 7. The Earths. 8. The Acids. 9. Salts, Crystallization, and the New Nomenclature. 10. Oxydation and Oxygenization: 11. Combustion. 12. Explosion. 13. Spontaneous Combustion. 14. Warming Rooms.

1. REMARKS.

All substances in nature, with the exception of the oxygen and hydrogen gases, are perhaps composed of certain definite proportions of both negative and positive elements. Such as contain more of the elements in which the negative electric fluid is inherent are called "the supporters of combustion;" and on the contrary, such as contain a larger proportion of the positive than of the negative are called *combustible* substances. Now as combustion is a mere combination of the different electric elements, the above distinction does not seem to be philosophically correct; for we see no reason why the negative elements have not as good a claim to be called combustibles as the positive. But as the process of combustion was long known before its real nature was understood, the materials were so named before it was ascertained, that the oxygen gas of the atmosphere contained one of the elements of the caloric produced. It was then supposed that the caloric chiefly resided in the combustible material, and that atmospheric air was merely necessary, some how or other, for its extrication.

As caloric, so far as is known, is composed of unvarying proportions of the two electric fluids; and as the integrant

matter of our planet, so far as we can ascertain, is composed of nearly equal proportions of negative and positive elements;—we may reasonably conclude, that there is an equal quantity of each kind of elements; or, what expresses our meaning more correctly, that there is the same exact proportions of the electric fluids: so that, was the Almighty FIAT given, the whole of our planet might vanish in a flash of fire, and a small globe of crystalline matter, or utter annihilation:—which, if viewed from a distant part of the universe, would only resemble one of those small meteors, that in a clear autumnal evening, play about in the aërial regions, surprise us with their brilliancy, and then, perhaps, disappear for ever.

All compound substances may be divided into two classes: combustible and incombustible. The combustible are those wherein the elements are the least intimately combined; or, such as contain a large portion of the positive elements with a small quantity of the negative; consequently, the positive have parted with few definite proportions of their inherent electricity. Among these, all vegetable and bituminous substances claim the first rank. In a philosophical point of view, certain substances, ranged under the head of "The supporters of combustion," may be placed in this class; viz. nitre, and some of the acids; because, in these the negative elements so much prevail, that they have parted with little of their electric fluid. But as the oxygen contained in the atmospheric air, is the grand storehouse of this fluid, whence all combinations are chiefly supplied, these substances are comparatively small in quantity. The incombustible substances are the most equally compounded of the positive and negative elements, and are such as have parted with many definite proportions of the inherent electric fluids; so that, under whatsoever circumstances, when presented to other substances, they refuse to combine, being already exhausted of the electric fluids. Among these are the earths, alkalies, and oxides, with certain of the acids, and the combinations of all these, which are ranged under one general term, viz. salts.

The quantity of chlorine and iodine, when compared with that of oxygen, is very small; hence it is customary in chemical language to speak of oxygen as the sole vehicle of the negative electric fluid. Some have supposed, that fluorine and even silica may be numbered with these supporters of combustion; however the latter seems only to consist of a peculiar base,

that combines with and neutralizes nearly its own weight of oxygen.

2. OXYGEN.

OXYGEN, on account of its being the chief vehicle of the negative electric fluid, is, the most active and energetic principle in nature. It is, besides, the most abundant, the most extensively diffused, and the most regularly disposed of all the elements. Hardly any thing in its natural state can be found without its being combined with some of this element; and it is with the greatest difficulty that it can be separated from its combinations; so that the history of oxygen, its compounds, and its laws of combination, form the principal part of modern chemistry.

Oxygen gas, in which state it can only be obtained alone, was discovered by Dr. Priestly on the 1st of August, 1774: he named it dephlogisticated air. It occupies about 750 times more space than when combined with hydrogen to form water, and one hundred cubic inches weigh about 34 grains.

According to its combinations, or the number of proportions of the inherent elctric fluid that it retains, oxygen possesses all the opposite qualities. In general we may say of it, that if it is combined with a basis, which has a very strong affinity for it, that is, has caused it in the combination to give out many proportions of its electric fluid, it is neutralized, or rendered harmless, mild or sweet. But if not combined with such a basis, or so exhausted of its electric energies, or, what means nearly the same, if combined in a greater proportion than the base will cover,—it is pungent, sour, corrosive, and destructive. These properties are caused by its quitting that basis to join with the other substances presented, for which it has a stronger affinity. Thus; when 74 parts oxygen are united with 26 of nitrogen, the corrosive qualities of oxygen are all displayed. This combination is known by the name of nitric acid or aquafortis. And as animal or vegetable substances are principally composed of carbon and hydrogen, for both of which oxygen has a stronger affinity than for nitrogen, this acid corrodes them. If a little of it is dropt upon the hand, the hydrogen and carbon are torn from their arrangement in the skin and fleshy fibres. The former, uniting with a portion of oxygen, forms water; and the latter, uniting with another portion, forms carbonic acid; the nitrogen escapes either as nitrous oxide or nitrogen gas, and

the two electric fluids form caloric. A hole is therefore made in the hand, heat is produced, and we truly say that the place is burnt; for combustion in all cases, as will be hereafter shewn, is the selfsame process.

The reason that oxygen unites thus rapidly with the animal substance, though it has parted with some proportions of its electric fluid to combine with the nitrogen in the formation of the acid, while it has no effect upon it while existing as gas in the atmospheric air, though it then has the full charge of the negative electric fluid, depends upon its very high degree of concentration in the acid, and its electric energies not being in the same proportion diminished. In water, the oxygen is more highly concentrated; but then it is combined with hydrogen, and so completely covered, or divested of so much of its electric fluid, that it produces no effect when applied to animal substances, and is therefore tasteless. This is the only combination it forms with hydrogen; but with hydrogen and carbon its combinations are infinite. Such compounds wherein it exists nearly in the same proportion as in water, are sweet. If the proportion of oxygen is less than the aqueous, the substance is spirituous or resinous; but if greater, it is sour. However, as these are all vegetable substances, wherein the elements are, perhaps, not combined according to the strict laws of chemical affinity, by reason of their having been elaborated by vegetable life, and are still perhaps partly under its arrangement, they form some exception to the general laws which govern unorganised matter;—for though chemical affinity is the grand mover of nature; yet, there are grounds for believing that life imposes new laws upon it, or occasionally suspends its operations.

In atmospheric air oxygen exists in the state of gas; but as it is then blended, not chemically combined, with nitrogen gas, in the proportion of 21 oxygen to 79 nitrogen, it is in a very dilute state; and has therefore no greater effect on animal and vegetable substances than to produce the irritation of a sore in the living fibre, or a slow putrefaction in the dead, and fermentation or acidification in vegetable matter.

Oxygen gas, from its being the only gas can be breathed, has been called *vital* air. By drawing the atmospheric air into the lungs, we imbibe into the blood from an eleventh to a sixth part of the oxygen, which is the source of animal heat, by its negative fluid uniting with the positive of the food, and thus main-

taining combustion throughout all parts of the body. (see Chap. XX. s. 3.) But when oxygen gas is breathed alone, it has the power of stimulating the circulation and secretions to a very high degree. If a person, whose pulse beats 60 or 70 times per minute, is made to breathe oxygen gas, in a few minutes his pulse is raised to 120 or 130; and his feelings are as if a tenfold acquisition of life and vigour had instantly rushed into his frame. But were it breathed alone for any considerable time, it would stimulate the system too much; the circulating fluids would either burst or soon wear out their channels, and death or premature decay would ensue. To prevent this, it is mixed with near four times its quantity of a gas to form atmospheric air, that is destructive of life. This too much vivifying principle of oxygen gas, is, therefore, counteracted by the opposite qualities of nitrogen, sometimes called azote, the depriver of life.

But though this simple mixture of nitrogen and oxygen forms atmospheric air; yet, some of their chemical combinations may be breathed. One measure of oxygen gas, and two of nitrogen form a gaseous compound named nitrous oxide gas. "Persons who have inhaled this gas have felt sensations similar to intoxication. Its effects on some people are truly ludicrous, producing involuntary muscular motion, and a propensity to leaping or running; on others, involuntary fits of laughter; and in all high spirits and the most exquisitely pleasurable sensations, without any subsequent feeling of debility. When Mr. Robert Southey, the Poet Laureat, inhaled it, he declared that it produced in him sensations perfectly new and delightful; and for several hours afterwards he imagined that his taste and smell were more acute than usual. In a poetical rhapsody, he remarked that he supposed the atmosphere of the highest of all possible heavens must be composed of this gas." A person's pulse may also be lowered by extracting oxygen gas from the air which he breathes.

Oxygen is the principle of oxydation, or that which combining with the metals, forms rust; which products were once called calces, but are now denominated oxides. A larger dose with some of the metals, and likewise with some of the other combustible substances, forms acids; though with some of the metalline substances it forms alkalies; and with others, earths. The earths, the alkalies, and the oxides, combining with the acids, form salts. But the earths alone, and the salts, are the most abundant substances in nature; for of them are all rocks

composed: sandstone is a specimen of the former, being formed of the earth silica; and limestome is a salt, composed of lime, which is an earth, and carbonic acid.

Besides these combinations, oxygen is the principal cause of fermentation, putrefaction, and combustion. By the first of these, many very important operations in life are performed, such as making bread, beer, wine; and on it depends also the art of distillation. By putrefaction, all useless and refuse animal and vegetable substances are reduced into their elementary forms; or take such arrangements as fit them for the food of new plants; hence the earth is cleared of a useless mass of dead vegetables and offensive animal remains, which would be a complete hinderance to vegetation. It is also the supporter of combustion; or that without which, it would be impossible to light or maintain our common culinary fires. For the principle on which fires burn, is, the union of the positive fluid inherent in the carbon and hydrogen of the coal, candle or wood, with the negative of the oxygen contained in the atmospheric air. (For all of these, see their respective sections in this chapter.)

3. CHLORINE OR OXYMURIATIC GAS.

THIS substance is the base of muriatic acid, but was for a long time considered as a compound of that acid and oxygen; and was, therefore, called *oxymuriatic* acid. At length Sir. H. Davy decomposed muriatic acid; and found it to be hydrogen united to a peculiar gaseous substance of a yellowish green colour, which he from this circumstance named *chlorine*.

It is in a gaseous state at and above the temperature of 40deg.; but below that, is liquid; and at 32deg. or below the freezing point of water, forms solid crystals. Its specific gravity is 34 times that of hydrogen gas. Being a vehicle of the negative electric fluid, it in some respects resembles oxygen. It will support combustion but cannot be breathed. A philosopher named Pelletier by accident inhaled a large quantity of it, and a consumption of the lungs and speedy death were the consequences. Even a very small portion of its fumes, mixed with atmospheric air, has a very disagreeable odour, and a very pernicious effect on the lungs; though it is found to be very efficacious against contagious and infectious fevers. For this purpose it is used in the navy and in military hospitals. On common occasions, it is only necessary to mix in an opon ves-

sel two parts common salt and one black oxide of manganese, place it in the sick room, and pour upon it two parts sulphuric acid. "Tradition tells us, that while the great plague was making havoc amongst the inhabitants of Shields, it spared the persons who dwelt about the *salt* works."

Chlorine corrodes or burns all the metals with great rapidity, and is the only substance that will dissolve gold and platina. Nitro-muriatic acid, from this circumstance called aqua-regia, will do the same; but chlorine enters largely into the composition of this acid, and may still, therefore, be considered as that which produces the effect. If any of the metals be beat into very thin leaves, or be reduced to powder, and be suspended or thrown into a jar filled with chlorine gas, provided the temperature is not lower than 70 degrees, they will immediately inflame, and produce a very brilliant phenomenon resembling a shower of fire. It discharges or destroys all vegetable colours, and is therefore used in bleaching. The seeds of plants, indigenous to hot climates, and which will not germinate either in our gardens or hot-houses, if previously steeped a week in chlorine gas, are said to grow freely.

Chlorine combines with oxygen in two proportions, yet not by simple mixture. But when hyperoxymuriate of potash is distilled, a gas is liberated compounded of oxygen and chlorine, which Sir H. Davy called Euchlorine. It is of a higher yellow than chlorine, has the smell of burnt sugar, and is very explosive. The second combination contains more oxygen, and is still of a higher colour. It also combines with nitrogen in the proportion of 91·2 chl. to 8·8 nitrogen:—forming the most dense of all fluids, with a specific gravity of 16·53; nor can it be solidified. It likewise unites with all the simple substances except carbon, which requires the intervention of a third, as hydrogen, to make them combine; under no circumstance will it combine with charcoal.

Muriatic acid. Hydrogen and chlorine readily unite. Should equal measures of each be put into a jar, and exposed to the light, (not to the solar rays for then they will explode,) they will combine, and condense into muriatic acid. This acid is gaseous, which form it keeps at all temperatures. When thrown on ice it melts it, but produces intense cold. The liquid muriatic acid of commerce is water saturated with this gas.

Though muriatic acid removes the stains of common ink, it does not affect printer's ink; and is therefore recommended for

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cleaning old books and prints; but for this purpose, it should be mixed with one sixth its weight of red lead. Writings defaced with this acid, may nevertheless be recovered by the use of sulphuret of ammonia and prussiate of potash. Chloride has no effect on ink mixed with indigo and oxide of manganese.

Common table salt is composed of 46½ muriatic acid, and 53½ soda. Soda consists of 76 metallic base and 24 oxygen. Therefore, when muriatic acid and soda are mixed in the above proportions, they form wet salt. The hydrogen of the acid combines with the oxygen of the alkali, and they form water, which is evaporated in drying the salt, and perhaps a true chloride of sodium remains. But the present chemical name of table salt, is, *muriate of soda.* Its antiseptic qualities are well known, and depend upon its forming a chemical union with the animal substance, and thus preventing it from combining with oxygen the cause of putrescency. As a manure, it promotes the health of plants; and this, principally by rendering their roots unfit for the habitation of insects, for the destruction of all kinds of which, as also of noxious weeds, no substance is so efficacious. It is particularly recommended for the roots of fruit trees, and also for potatoes and turnips: one bushel per acre is said to be a sufficient dressing for meadow land; and that a larger quantity will do harm rather than good. It should be well dried in an oven, ground very small; and, then laid on, in winter, principally on the middle of the ridges, like sowing small seeds. Too great a quantity is a great sterilizer of land, and among the ancients was considered the emblem of barrenness: hence, to sow a ruined city with salt was to consign it to everlasting desolation. On account of this property, it has been found useful for preventing the dry rot in ships when they are well suffed with it.

Muriate of Soda is a very abundant mineral; it is found not only in large beds and masses, but also in many springs and lakes, in almost all soils, and it forms about a thirtieth part of the waters of all the seas. Rock salt is sometimes crystallized in the form of a cube, which is that of its primary crystal; it is either opaque, translucent, or transparent, and its colour is very various, as white, grey, reddish brown, brick red, violet, blue, and green; when coloured it is always more or less impure.

The sodalite, and one or two more earthy minerals, contain a small portion of muriatic acid; it also occurs in some ores of lead, quicksilver, silver and arsenic, but in none above 3 per cent.

The muriates in general are the most volatile of all the salts, and yet the least affected by excessive heat. With a larger dose of oxygen they form hyperoxymuriates. But this class of salts, when mixed with combustibles, is very dangerous from their explosive qualities. The French attempted to use that of potas, composed of 28 chlorine, 38 oxygen, and 34 potassium, instead of nitre in the manufacture of gunpowder; but during the process it exploded and proved fatal to two individuals. However it has been supposed that in one of their campaigns, they made use of gunpowder thus manufactured; and it is now the percussion powder used by sportsmen.

4. IODINE.

THIS newly discovered substance is obtained, in very small quantities, from kelp and some other sea-weeds, combined with potas or soda. In its simplest form, it consists of small rhomboidal, blackish coloured crystals. Like oxygen and chlorine it is evolved from the positive end of the voltaic apparatus. Also when a piece of potassium is suspended in the vapour of iodine, it will inflame and burn with a pale blue light. Phosphorus, also, when heated burns very rapidly in this vapour, throwing out much heat, and this without the intervention of oxygen: hence this substance is ranked among the supporters of combustion. It melts at 225 deg. and at 350. is converted into vapour of a violet colour, whence its name. One hundred cubic inches of this vapour weighs 262 grains.

Iodine combines with hydrogen and chlorine forming acids, and by means of euclorine, may be made to combine and form an acid with oxygen, that acts rapidly on gold. It, also, combines with all the metals and forms iodurets, but its chief affinity seems to be for potassium. Starch is a test for iodine, with which its presence may be detected. They form a precipitate of a brilliant blue colour, inclining to purple. It was only discovered in 1812, and is therefore only as yet used in some costly pigments. It is of great service in medicine for dispersing goiters, and other indolent tumours arising from scrofula.

5. OXIDES.

WHEN oxygen is combined with any of the simple substances, in a less proportion than to render it acid to the taste, the com-

bination is called an *oxide*. In general, oxygen will combine in two, sometimes three different proportions with each of the simple substances; so that the whole number of oxides must be considerable. That combination which contains the least proportion of oxygen is sometimes called, the *protoxide*; the next, the *deutoxide*; and the third, which is generally the greatest quantity with which it will combine, is distinguished by the term *peroxide*. But in the following pages they are distinguished by their colour.

Water is an oxide of hydrogen; and the rust of iron may be instanced as a specimen of metallic oxide. The oxides, generally, have a greater specific gravity than the metals of which they are composed; and are always heavier than their respective metals in the same proportion as the oxygen combined: so that in the succeeding pages, when the quantity of oxygen combined is stated, weight is always referred to. The metallic oxides are mostly in a pulverized state; and may be reduced by being intensely heated with powdered charcoal, or with any substance that has a stronger affinity for oxygen than the metal with which it is combined. The degree of attraction, which the different metals possess for oxygen, is, in the following order;—manganese, zinc, iron, tin, antimony, arsenic, nickel, cobalt, copper, bismuth, mercury, silver, gold, platina.

6. THE ALKALIES.

OXYGEN combines with two of the metalloids, viz. potassium and sodium, in three proportions each: the two middle ones are distinguished by the term alkalies. These two alkalies, *potas* and *soda*, together with the newly discovered alkali, *lithia*, are called the *fixed* alkalies; because they will not volatilize without a great heat; also to distinguish them from the fourth alkali, called the *volatile* alkali; which is a compound of hydrogen and nitrogen, and is volatile at all temperatures. (see *ammonia*)

The distinguishing characteristics of the alkalies, are, their peculiar acrid taste, their property of changing the blue juices of vegetables to green, the yellow to brown, rendering oil or tallow miscible in water, and acting as powerful caustics when applied to the flesh of animals.

7. THE EARTHS.

THE combinations of oxygen with nine of the simple substances or metalloids are distinguished by the name, *earths*. They unite but in one proportion. Five of them are called simple earths, viz. *silica*, *alumina*, *zirconia*, *glucina*, and *ittria*. They are so distinguished because they have neither taste nor smell, except glucina, which is sweet to the taste. The other four are called alkaline earths, viz. *lime*, *barytes*, *strontites*, which are like the alkalies in taste, causticity, solubility in water, and in their effect on vegetable colours; and *magnesia*, which is similar to the alkalies only in the last property. But in several respects they all differ from the alkalies, as well as from each other.

To these nine earths, a tenth has lately been added, called *thorina*. It is found in the mineral called Gadolinite, in the proportion of 30 per cent.; though it is not always one of its component ingredients. It also occurs in the deuto-fluate of cerium, and in the double fluate of cerium and ittria. Its colour is perfectly white; it is not fusible by the blow-pipe unless mixed with borax or phosphate of soda, when it forms a transparent glass; in some of its properties, it differs from all the earths, but it has not been subjected to the action of the galvanic apparatus.

All the earths are nearly unalterable in the fire, unless when mixed with certain other substances, which render some of them very fusible. They are either insoluble in water or nearly so, and more especially when they are combined with carbonic acid; with which and other acids, as well as with metallic oxides, they are often found united by nature; being the chief ingredients, not only in the solid structure of the globe, but also in spars, gems, and precious stones of almost every description.

8. THE ACIDS.

WHEN oxygen is combined with one or more of the simple substances, and the compound imparts a sour taste to the tongue, it is then called an *acid*. Though some substances are classed with the acids, which have not this sour taste; and there are some few acids which do not contain oxygen, as fluoric, muriatic, &c.

The general characters of the acids, are, that besides their

taste, they change the blue, green, and purple vegetable juices to red; and combine with the metallic oxides, earths, and alkalies in the formation of salts. Indeed metals must be reduced to oxides before they are soluble in the acids; such acids as dissolve them, oxidize them during the process.

Some of the simple substances combine with oxygen in three proportions. Sulphur for instance;—the first combination forming an oxide; and the other two, acids. The acid, which contains the least proportion of oxygen, is distinguished by the termination *ous*, as sulphurous or nitrous acid; and that which contains the most, by the termination *ic*, as sulphuric or nitric acid.

Acids may be divided into two classes: the first consisting of those, which contain only one base united with oxygen, and which cannot be decomposed without being heated with powdered charcoal. The second class consists of acids having two or more bases, and which decompose by mere heat.

The *first* class of acids: the sulphurous and sulphuric, the muriatic and oxygenized muriatic, the nitrous and nitric, the phosphorous, and phosphoric, the fluoric, the boracic, the arsenous and arsenic, the tungstic, the molybdous and molybdic, the telluric, chromic, and the carbonic. These are all mineral acids.

The *second* class of acids: the acetic, oxalic, tartaric, citric, malic, lactic, gallic, mucous, benzoic, succinic, camphoric, and suberic: these are all vegetable acids. The laccic, prussic, sebacic, uric, amniotic, and the fluorboric;—these are all animal acids, except the last, which is mineral.

The vegetable acids have for their bases various proportions of carbon and hydrogen; and the same, with nitrogen, form the basis of the animal acids. All the acids of both classes are generally fluid, but some of them are gaseous, while others may be crystallized;—their individual properties will be treated of when we come to their kindred substances. With the oxides, alkalies and earths, the mineral acids take a solid form, and thus compose a large proportion of the most abundant of rocks. The oxides (or metals) are chiefly found with the carbonic, phosphoric, sulphuric, muriatic, tungstic, chromic, molybdic, and arsenic acids. The alkali potas, with nitric and carbonic; and soda, with carbonic, sulphuric, muriatic, and boracic acids. Combined with the earths, are, carbonic, phosphoric, fluoric, sulphuric, muriatic, nitric, tungstic, boracic and arsenic.

Besides the above, there are a few other acids sometimes mentioned, but they are not much known. Acids in general have various uses both in art and nature. The sulphuric seems to be the grand operator in reducing rocks, especially limestones and the lavas of volcanoes, to a pulverized state, and thus rendering them subservient to vegetation.

9. SALTS, CRYSTALLIZATION, AND THE NEW NOMENCLATURE.

THE combination of the acids with the oxides, alkalies, and earths are distinguished by the general term, *salts*. Before they solidify, or when salts are dissolved in water and suffered to cool remaining at rest, they shoot into crystals. Though some of the mineral salts assume the crystalline texture after the mass has assumed the solid state. What is very remarkable, every salt has a manner of crystallizing peculiar to itself; and forms crystals differently shaped from those of any other salt. Whatever size the mass of the salt may be, whether the vast rock of the mountain, the small pellucid gem, or the diminutive sparkling cube of common table salt, all are formed according to the arrangement which the original particles or molecules assume among themselves, and according to the peculiar manner of the crystallization of that salt. And whether the artist would split or polish a block of marble, or a precious gem, he must do it, if he would do it successfully, according to the grain of the crystal.

In most cases crystals cannot be formed without water, and to its presence is generally owing their semitransparency; yet, some salts crystallize without water, others with very little, but some require more than their own weight. This water is always in definite proportions, becomes an integrant part of that salt or crystal, and is called the water of crystallization. That water, which remains after the crystals are formed, is called the *mother waters:* it is also in definite proportions, being that necessary to hold the salts in solution. But generally two or three crops of crystals may be obtained from the same water. Light is found to be a great promoter of crystallization; indeed some salts will not crystallize without being exposed to it: and in all cases, that side of the vessel, which has the most light, crystallizes better than the other.

Some salts, when exposed to the air, lose their water of crys-

tallization and fall into powder; others attract water from the atmosphere and become liquid; in the former case, they are said to *effloresce*, and in the latter, to *deliquesce*. Though some salts thus dissolve by mere exposure to the air, others will hardly dissolve in water, and some not at all. If they require more than 1000 times their weight of water to dissolve them, they are generally said to be insoluble in water. All salts dissolve more rapidly in hot water than in cold, except muriate of soda.

But this account of crystallization is not confined merely to salts or the chemist's labratory; for all substances both simple and compound, when solved either by heat or any other solvent, under favourable circumstances, always crystallize while becoming solid. If melted metal stand and cool till a crust be formed over the surface, and that crust be taken off and examined, the crystalline texture will be seen. The crystalline form of tallow or fat is evident on the surface or round the edges of a dish wherein it has passed from a fluid to a solid state; and water, soon after being cooled to the freezing point, begins to shoot into crystals of incipient ice. "In combinations," says Sir H. Davy, "certain bodies form regular solids; and all the varieties of crystalline aggregates have been resolved by the genius of Haüy into a few primary forms. The laws of crystallization, of definite proportions, and of the electric polarities of bodies seem to be intimately related; and the complete illustration of their connection will probably constitute the mature age of chemistry." See Mineralogy, Chap. XII.

The salts are supposed to be 2000 in number; but though they are so many, the chemist, by what is called the new nomenclature, is enabled to recognize them all with their composition as easily as if there were no more than two or three.

Each salt has two names; the first signifying the acid, and the other the base. If the acid ending in *ic* is used, then the salt is known by ending in *ate;* as sulphate of iron, composed of sulphuric acid and oxide of iron. If the acid in *ous* is used, the first name of the salt ends in *ite,* as sulphite of soda.

When two simple substances are combined together without the intervention of oxygen, they are known by the termination *et,* as sulphuret of iron, that is, iron and sulphur (martial pyrites) but no oxygen. Carburet of iron, &c.

Salts are called neutral salts, when the acid and the base are combined in such proportion, that they completely cover each other:—in this case they will not act on any thing without being

decomposed. But should there be an excess of either acid or base, they have other distinctions. If the acid predominates, the salt has the word *super* prefixed, as supertartrate of potas. But if the base exceeds the acid, then, the word *sub* is used, as subborate of soda.

The advantages arising from the adoption of the new nomenclature, are evidently very great. By the old mode of naming salts, no true idea whatever was conveyed of their composition; but very often an erroneous one. For instance, green copperas conveys the idea of containing copper; whereas it is composed of sulphur, oxygen and iron, and is what is now called sulphate of iron. Any one using the word Glauber's salts, Epsom salts, or gypsum, would convey no idea of their composition to another. But call them by their new names, sulphate of soda, sulphate of magnesia, and sulphate of lime, and he knows at once their composition. Black lead is another instance of erroneous appellation; it contains no lead, being a carburet of iron. The same remarks will apply to some of the acids. Sulphuric acid was once called oil of vitriol; whereas it has no property whatever of an oil, being composed of sulphur and oxygen; but all pure oils are composed of carbon and hydrogen.

10. OXIDATION AND OXYGENIZATION.

THOUGH the principle of all the combinations of oxygen is the same; yet, by reason of the different affinities, as well as the disposition of the elements, its modes of combining may be divided into three classes; viz. oxidation, and oxygenization, combustion and explosion.

When a substance is combined with a less quantity of oxygen than constitutes an acid, it is said to be oxidized; but if an acid is formed, it is then distinguished by the term oxygenized; though these distinctions are not always observed.

Oxidations are continually, though in many cases, imperceptibly going on. Even the air we breathe is converted both into an oxide and an acid within the body. A part of it combines with the hydrogen composing our food, and forms water; and another part combines with the carbon and forms carbonic acid. These are also formed at the dissolution of animal and vegetable substances; most of the metals are oxidized when exposed to the air, especially if moist. But in most of these cases, except during the putrefaction of some animal substances, an old log

of wood, or wherever there is phosphorus, no light or heat is perceptible: it being so much dissipated by the slowness of the process. Yet the products of all combinations are the same, viz. oxides, alkalies, earths, acids or salts. Hence all substances, as has already been stated, may be divided into two classes, viz. combustibles and incombustibles.

That the metals are combustible, one instance may serve as a proof. Take a thin shaving of iron, or a piece of very small wire of that metal, and twist it into the shape of a cork-screw. Fix on one end a piece of cotton dipt in tallow, or a piece of inflammable wood, and fasten the other end to the underside of a cork, that will just fit the mouth of a glass jar filled with oxygen gas. Then light the cotton or wood, and put it and the wire into the jar, stopping the mouth with the cork. While the metal is thus suspended, it will be seen to burn or unite with the oxygen gas, throwing out the most brilliant sparks and corruscations of light, and producing a very striking phenomenon. If the product be carefully examined, it will be found to consist of the black or green oxide of iron, and will weigh exactly as much as the conjoined weights of the gas and metal consumed. Several other instances of the combustibility of the metals in oxygen gas, as well as in chlorine gas, might be given; but this will suffice for the present, as we shall have to mention them when we treat of the metals.

When saccharine liquors are exposed to the air, under favourable circumstances, they undergo three successive fermentations before they arrive at the ultimate arrangement of carbon and hydrogen with oxygen. Each fermentation is effected by the materials imbibing a fresh dose of oxygen from the atmosphere, and by the carbon and hydrogen uniting, perhaps, more closely with that already possessed. For, though all vegetable juices contain a considerable quantity of oxygen, they do not contain the definite proportion of water and carbonic acid; and, therefore, the oxygen which they do contain is, perhaps, not very closely combined till more is obtained from the atmosphere. Thus: 100lbs. of sugar consist of 64lbs. of oxygen, 28lbs. of carbon and 8lbs. of hydrogen. Now 28lbs. of carbon will require for the formation of carbonic acid, 72lbs. of oxygen; and 8lbs. of hydrogen will require 58lbs. 9oz. of oxygen for the formation of water; but $72+58{\cdot}9=130$lbs. 9oz. of oxygen; and the sugar contains only 64lbs.: therefore, previously to 100lbs. of sugar arriving at its ultimatum of oxygeni-

sation, it will take in three distinct doses of oxygen, till it has imbibed no less than 66lbs. 9oz. from the atmosphere. It is perhaps necessary to remark, that, before sugar will ferment and acidify rapidly, a large quantity of water must be added as a menstruum, and yeast to commence the fermentation; but this does not affect the principle of the above calculation. The bubbling up, which we called fermentation, is caused by the caloric escaping, produced by the union of the electric fluids; and, also, by the continual evolution of the carbonic acid, which is all the while flying off and escaping into the atmosphere.

Besides the above process in vegetable substances, oxygen is also the cause of rancidity in butter, oil, candles, salt meats, &c. by combining with their carbon and hydrogen, and producing in them sebacic acid.

11. COMBUSTION.

The substances generally used for combustion, are, if we consider coal and other bituminous fossils of this origin, vegetable productions, and the fat of animals. They are the storehouses of the positive electricity, and want of density or cohesive attraction is their most prominent characteristic. Their texture, therefore, being loose, they are the more easily dissolved; and the oxygen, original particle with original particle, combines with the greater facility. In general, a high temperature is necessary for the commencement of the combination; but occasionally they contain a sufficiency of latent caloric for this purpose—only it requires its energies resuscitated by compression or friction. Such is the quantity of latent caloric in iron, that by smart hammering it may be made red hot; and by the percussion of flint and steel a particle of melted iron is struck off. But in all substances friction produces heat, by exerting a very great compression on a very few particles: for even in striking a light the blow must be given in the manner of friction, so that the steel must be struck by the flint obliquely, and not perpendicularly to its surface. Caloric thus put in motion, even in wood, is sufficient to commence its combination with the oxygen of the atmosphere. The inhabitants of some parts of America, and of some of the South Sea islands, are said to have a mode of producing fire by rubbing two pieces of hard dried wood rapidly together. The friction, arising from

the violent agitation of the branches of trees by the wind, is said to have set forests on fire in America; and accidents in machinery, caused by their being set on fire by friction, frequently happen.

When combustibles, such as wood, coal, or oil, are heated in the air to a certain temperature, viz. 800 degrees, all of a sudden they commence a rapid combination with the oxygen gas of the atmosphere, throwing out a vast quantity of light and heat, formed by the union of the negative fluid of the oxygen and the positive of the hydrogen and carbon of the combustible. One portion of the oxygen unites with the hydrogen to form water, which escapes as invisible vapour; and the other with the carbon to form carbonic acid gas, which is also invisible. Oxides or acids are always produced by combustion, as well as by all other chemical combinations, where oxygen is an agent. And should a combustible be composed of a number of simple substances, they will, during the process, take in a doze of oxygen sufficient to convert them into their respective oxides, alkalies, earths or acids.

That we may have some idea of the combustive process by calculation, we will take a lamp with olive oil for the combustible. Now the cotton which forms the wick is composed of carbon, oxygen and hydrogen; and the oil is composed of 79 carbon to 21 hydrogen per cent. Before the wick or oil attains the temperature of 800 degrees, part of it, viz. the hydrogen with some of the carbon, is converted into carburetted hydrogen gas: the flame is this gas combining with oxygen. For, flying off in a stream, the hydrogen is inflamed first, and is combined principally at the lower part of the flame; and burning with a faint, almost invisible, blue flame, occasions the flame to appear blue around the bottom: and as the gas is formed at a lower temperature than that at which the combination with oxygen commences, so the lower part of the flame does not exactly touch the wick. The heat, which the hydrogen thus produces, renders the carbon red hot, when it combines also; which, burning with a red light, gives that colour to the upper part of the flame. But should the ignited part of the wick be so long that the gas is combined at the bottom, and at such a distance that there is not heat sufficient to raise the remaining carbon of the wick to a combining temperature, it will escape as thick smoke, causing a dim light. If this smoke be collected, it will be found to be charcoal or lamp-black. On such occa-

sions we usually remedy the defect by the application of the snuffers.

Now that we may ascertain the quantity of oxygen gas thus combined, and also the quantity of the products. Light and heat we cannot measure. But for the sake of convenience in calculation, we will suppose 100 oz. of olive oil consumed; and taking no notice of the wick, we shall have 79 oz of carbon and 21 oz. of hydrogen. The carbon, therefore, taking in its full dose of oxygen, which as well as hydrogen it always does in combustion, will produce 282¼ oz. of carbonic acid; and the hydrogen, 175 oz. of water. Therefore, 357¼ oz. of oxygen will have been taken from the oxygen gas of the atmosphere. Mixed with this gas were about 1178¾ oz. of nitrogen gas; which together make 1536 oz. of atmospheric air. And as a cubic foot of atmospheric air at the earth's surface, and at the mean temperature of our climate, weighs about 1¼ oz.: consequently, for the combustion of 100 oz. of olive oil, 1152 cubic feet of atmospheric air are required,—which is the exact quantity contained in a room 12 feet square and 8 feet in height. Were this oil, therefore, so burnt in that room, and the doors and windows so tight that no fresh air could be admitted, at the time when the oil was consumed, the whole of the oxygen gas would be combined; and as it takes just a cubic inch of oxygen gas to form the same bulk of carbonic acid gas, and the nitrogen remains unaltered, therefore, the room would contain the same measure of gases as before. But as there would exist 175 oz. of water, some condensed perhaps against the ceiling, and walls, and the other still in vapour, the room might be said to be fuller,—its contents being more compressed. But as it now contains no oxygen gas, it is evident, that were an animal in the room, it would soon be deprived of life for want of vital air.

However it is ascertained that atmospheric air, after it has been once breathed, is so loaded with vapour and carbonic acid gas, and deprived of so much oxygen, that it will not support combustion. Now it is found to lose at one inspiration about a sixth part of its oxygen; and allowing no more vapour and carbonic acid to be respired than is formed from the inspired oxygen, it perhaps might require the air of five or six such rooms for the combustion of the oil.

According to Lavoisier, a middle sized man in good health consumes in 24 hours 32 oz. troy of oxygen gas, which is 640

grains per hour. And as 100 cubic inches of oxygen gas weigh 34 grains, he will consume 1882 cubic inches every hour. Now at each inspiration he takes into his lungs 42 cubic inches of atmospheric air; and as he makes about 1200 inspirations per hour, he must, at each inspiration, take into the blood 1·56 cubic inches. He would therefore consume all the oxygen of the above room in 267 hrs. 50 min.; or breathe the air all once over in 39½ hours.

The process of combustion in all common fires is the same, only the combustible materials are not so well disposed; and gas, especially in common coal fires, is sometimes generated where there is not a sufficiency of heat to inflame it. In this case, it never fails to carry off some of the undissolved materials, as coal oil, tar, and ammoniacal watery particles, which, ascending with the real products of combustion, form smoke and soot. But should there be any simple combustible present which will not volatilize in the common fire, as is the case with the metals, then the oxide, alkali, or earth remains among the ashes. But the main part of the ashes in our common coal fires, after the cinders or carbonaceous materials are consumed, consists of earthy substances, chiefly of the aluminous kind, which were component ingredients of the coal. The inflammable parts, or what are of real value, for nothing else gives useful light and heat, are hydrogen and carbon; and these leave no ashes. As soon as the hydrogen is gone, the flame ceases; because there can be no more inflammable gas generated. But the coke or cinders continue to afford a very intense heat, and carbonic acid gas alone is plentifully evolved, till the whole of the carbon is combined, and nothing remains but red hot earthy substances.

The quantity of smoke, that is, carburetted hydrogen gas, oil, tar, and undissolved flakes of carbon, extricated from common coal fires in large towns, and the fires of forges, steam engines &c, is very considerable; and doubtless very materially diminishes the salubrity of the atmospheric air. The public are, therefore, benefited by the Act of parliament which enforces the adoption of such fire places as occasion steam-engines to consume their own smoke; that is, by the admission of a blast of fresh air into the hot part of the flue, to convert all the carbon into invisible carbonic acid gas. But whoever will consider that carbonic acid gas is the ultimatum of all combustion of carbon; and how much is evolved from every fire

and candle, from putrefaction, and the lungs of the thousands of people and animals inhabiting populous cities; and reflect that this gas is what principally renders air unwholesome, must smile when he hears or reads of the enforcement of the above act, rendering the air of our crouded cities as salubrious as that of the open country.

12. EXPLOSION.

THE first and second classes of combinations are principally effected by the extrication of oxygen gas from the atmosphere; but the combustibles of the third class generally contain the oxygen among themselves. That is, some of the most inflammable of the combustible substances are mixed with an oxide, acid or salt, whose base has a very slight affinity for the oxygen with which it is combined. Gunpowder, and all fulminating compositions, are of this description.

Gunpowder consists of 15 carbon or charcoal, 9 sulphur and 76 nitre, per cent. Now nitre, (saltpetre, or nitrate of potas) consists of 46¾ potas to 53¼ nitric acid; which acid is composed of 26 nitrogen to 74 oxygen per cent. The composition of gunpowder will, therefore, stand thus: 15 carbon, 9 sulphur, 35·53 potas, 10·52 nitrogen, and 29·95 oxygen. Nitrogen and potas, which is already an oxide, have a very slight affinity for oxygen, and carbon and sulphur, when at a sufficient temperature, the greatest next to hydrogen of all known substances. Therefore, when these two simple substances and nitrogen are triturated together in making gunpowder, the nitre, (and consequently the oxygen,) is blended with the two combustibles, but they are not chemically combined.

The combustibles and oxygen are therefore brought together, almost original particle to original particle; so that when a spark falls upon such a composition, though ever so small, the particles on which it does fall are raised to the proper temperature for the combination. For it is found that the spark struck off by the collision of flint and steel is a globule of melted iron, and iron does not fuse till it acquires a most intense white heat; however a much lower temperature will cause the sulphur to unite. This spark then commences the chemical combination, and as the oxygen is already disposed, particle to particle, with the carbon and sulphur, there is no impediment, such as is caused by burning the same combustibles in the open air, when

the supply of oxygen must first pass to the place, be separated from the nitrogen, and the heat must decompose or rend asunder the materials before the oxygen can be admitted; consequently, the whole combines as quick as a flash of lightning. They are converted into their respective gases, viz. carbonic, and sulphurous acid gas. The nitrogen also takes its gaseous form, and some of the sulphur combines with the potas, and is what renders foul, and causes the disagreeable smell in a recently fired gun. The caloric produced by the union of the two electric fluids from the combining elements gives additional elasticity to what each gas possesses peculiar to itself; and thus are produced all the surprizing effects we see in blasting and gunnery.

The *Greek Wild-fire* was a curious composition used by the ancients. But the art of making it was lost so long that its having ever existed began to be doubted. When it was at length regained by the knowledge of chemical affinities, and soon after an old Latin manuscript, describing its composition, was found in the Library of the Elector of Bavaria. A portion of nitre, sulphur, resin, alcohol, camphor, and other combustibles are melted together, woollen cords are then dipped into the fluid and rolled up in balls. The end of the cord is set on fire, and the ball is thrown into the enemy's camp or ships. The combustibles are supplied with oxygen from the nitre, so that nothing can quench the fire, not even if the ball be plunged in water. It was discovered about, or not long after the time of Constantine the Great, and continued in use till the invention of gunpowder. The art of making it was preserved at Constantinople as the palladium of the state; and it more than once saved that city from the fury of the Saracens. At length it got into the hands of the Saracens, and was used with deadly effect against the Christians in the Holy Wars. It was employed with equal effect both by sea and land, in battles, and in seiges, being poured from ramparts in large boilers, or launched in red hot balls of stone and iron, or darted along with arrows and javelins. Sometimes it was used in fire ships, and blown through long copper tubes, from the prows. The orifices were fancifully shaped like the mouths of savage monsters, that thus seemed to vomit a stream of fire. In battles by land, it was occasionally hurled, by their large engines used for projecting ponderous stones, among the enemy, scattering terror and dismay. It is described, by those who saw it used by the

Saracens, as coming flying through the air like a winged long-tailed dragon, about the thickness of a hogshead, with the report of thunder and the velocity of lightning. It therefore wrought a great change in the art of war, but not such a revolution as that occasioned by the introduction of gunpowder.

Fulminating gold is an oxide of gold and ammonia, which will explode by a very gentle heat or slight friction. What were sold a few years ago under the name of fulminating and detonating balls, were a composition of hyper-oxymuriates of silver and sulphur. The hyper-oxymuriates, retaining a large quantity of oxygen by a very slight attraction, are very explosive. But as some have lost their lives, others their fingers and eye-sight by operating on these compositions, the best that can be said respecting them, is, in the way of endeavouring to deter all from tampering with them.

Explosions in coal mines are caused by carburetted hydrogen gas. What occasions explosion and not burning, as in a lamp, is, the inflammable gas being blended with the atmospheric air, so that the particles of the oxygen of the atmosphere are regularly disposed with those of the hydrogen and carbon, in the most favourable position for uniting without any motion from a distance; therefore, when entered by a lighted candle, the explosion of the whole is simultaneous, or as but one flash. Carbonic acid gas is here also formed, so that the workmen are always on their guard against the choke-damp, when a pit is entered that has been fired by the fire-damp. See Chap. XI. s. 4.

13. SPONTANEOUS COMBUSTION.

THIS mode of combination is nearly allied to explosion, since in most cases, it arises from the contact of oxides or acids with some of the most inflammable combustibles; some of which, as phosphuretted hydrogen gas, will inflame by mere exposure to the air; and others by mere mixture. When nitrous acid is mixed with half its weight of strong sulphureous acid, and then poured into oil of turpentine, the whole bursts into a flame with violent and dangerous splashings and explosions. The metalloid potassium inflames when thrown on water and even ice; and, if iron filings and flowers of brimstone are kneaded with water into a paste, the iron will decompose the water, absorbing the oxygen and disengaging sufficient caloric

to set the sulphur, and consequently the hydrogen, on fire, even though buried underground. Coals containing martial pyrites (sulphuret of iron) have taken fire spontaneously in damp cellars; and ships at sea have been so fired, and consequently lost, by their store or load of coals containing pyrites and being damp.

On this last principle of spontaneous combustion have some endeavoured to found a theory of volcanoes. Large beds of martial pyrites abound in the bowels of the earth in many parts of the globe. Therefore, when water oozes through the fissures of rocks and reaches these hidden mines, they take fire; and steam or gas, by its expansive force, lifts up the superincumbent earth, forming a hollow beneath into which more water enters; and the power is thus increased till the strong ribs of the world itself are rent asunder, and the earth's red hot entrails are spouted into the air with all the horrors and devastations of a volcano.

Charcoal, oily substances, and some substances that may chance to have oil spilled among them, when in large masses, are extremely subject to spontaneous combustion. Fermentation of every description, where the caloric produced cannot be dissipated, will occasion it. Instances of this kind are the most frequent among stacks of hay and corn, when they have been put together with too much moisture in them. The water serving as a solvent that commences a fermentation in the sap, in which is a great deal of oxygen along with its carbon and hydrogen. By the compressure, occasioned by so large a quantity of matter being piled up together, the elements enter into new combinations, evolving a large quantity of caloric, sometimes sufficient to inflame the whole.

There are several curious instances of spontaneous combustion mentioned in vol. VI. of "Polehampton's Gallery of Nature and Art." One of the human body in particular; viz. an elderly, sedentary woman, who had been much addicted to the use of spirituous liquors, when alone, caught fire, either accidentally or spontaneously; yet, though the whole of her body, bones and all, were consumed, so feeble had been the flame, that the chair on which she sat, was only black and oily, and not burnt.

14. WARMING ROOMS.

In the practice of warming rooms by our common English method of an open fire, a continual stream of air is always rushing towards the fire place to supply the combustion; and, of course, a fresh supply from without the room must be had, continually whistling and singing through the key hole or crevices of the door and windows. Should these be made air tight, it must be obtained down the chimney at the expense of a smoky room or a disagreeable smell. Because the vapour, the carbonic acid gas, the nitrogen gas, as also the fumes of sulphur which often abounds in coal, are evolved into the room, rather than carried up the chimney. For the principle on which smoke ascends, is, that of its being rarefied by heat. It is therefore pressed out of its place by the surrounding cold and dense air, and it rises upward like the ascension of an air balloon. But should the oxygen gas, that is to support the combustion, have to come down the chimney; or should the fire be closed at the top, so that the air is not rarefied by the heat at the most favourable place for ascending; or the fire place be so wide that the heated carbonic acid gas be cooled before it enter the gorge of the chimney, in which case it is heavier than atmospheric air, and of course will not ascend:—in all or any of these cases, a smoky room must be the consequence.

On the continent, rooms are generally warmed by a fire outside with flues going round like those in our garden hot-houses. By this method less fuel is needed, the rooms are free from smoke, and the inmates are kept more regularly warm, without the inconvenience of being exposed to currents of cold air, while the temperature of the room may be regulated by a thermometer. Foreigners consider their method much superior to ours; and pretend to laugh at the Englishman for burning his eyes out over a hot fire, merely because his forefathers did the same.

But if our method is faulty, we have many objections to theirs, on which we found our reasons for not adopting it. We have a plentiful supply of fuel from our coal pits, while its scarcity and high price often reduce them to great difficulties. And though we are more apt to catch cold within doors than they; yet, we generally have a sweet and wholesome room, from a continual supply of fresh air passing through it to the fire place.

Two or three persons with a few candles, as was shewn s. 11, would soon consume the oxygen gas of a close room, and extinction to the candles and suffocation to the persons would infallibly ensue. To our method is perhaps owing, in a great measure, the rosy complexion almost peculiar to the English nation. And the last reason for our continuation of it, and certainly the most endearing to an Englishman, is the effect of custom. He finds in his fire a cheering companion, capable of dissipating all his sorrows, or at least of alleviating his care and anxiety. When the storm rattles without, he has a continual source of pleasure within, from the stirring of his fire. At the blazing hearth he reaps with redoubled zest, the full harvest of domestic joys;—here, all his affections expand to the full tide of benevolence; here, his patriotism is enkindled, and his love of mankind fanned into flame; and here he analyzes his thoughts, separates them from the dross of sordid self-interest and love of the world, and presents them pure and simple before the throne of his Maker, his Redeemer and his God!

CHAP. XI.

The Simple Combustibles.

1. Remarks. 2. Hydrogen. 3. Nitrogen or Azote, Ammonia. 4. Carbon, Diamond, Charcoal, Carbonic Acid Gas, Carburetted Hydrogen Gas. 5. Boron. 6. Sulphur. 7. Phosphorus. 8. Fluorine. 9. Selenium.

1. REMARKS.

As we consider the electricities, not only as forming the band, but also as the grand instrumental movers of nature, we shall make them the leading subject in our description of all the simple substances which are considered as the store-houses of the positive fluid. And as we have no other mode of ascertaining the quantity of inherent fluid in each element, than by its combination with oxygen, we shall place the different oxides and acids at the head of the description of each substance; so that its electric energies may be judged of at the first glance. As the density of a substance is indicative of the cohesive attraction existing among its original particles, we shall also subjoin (where it has been ascertained) the specific gravity, in order that some idea may be formed of the intimacy of combination and mutual attraction existing among the original particles.

The reader will perceive a considerable difference among the substances of the three following chapters, with respect to their electric energies. All the simple combustibles combine with more than their own weight of oxygen, but none of the metalloids, combine with their weight; molybdenum and chromium, forming acids, combine with more than their weight, but the

other metals, except iron, nickel, cobalt, antimony, and arsenic, do not combine with above one-third, and silver with little more than one-fourteenth.

It is also remarkable, that those substances, which combine with the most oxygen, do not always enter the most readily into combination; hence it appears that chemical action depends upon a concentration of the electric fluids. Oxygen and hydrogen gas, in the aqueous proportions, may be blended together without producing any chemical action; but if they are concentrated by violent compression they will combine. From this as we shall afterwards shew, it is evident that the action of caloric depends first upon attraction and then upon repulsion. Attraction, while its elements are beyond a certain distance; but repulsion, when they are brought within that distance.

But though concentration is necessary for rousing the electric energies in any substance so as to overcome the cohesive attraction, or the affinity between the inherent electric fluids and their elementary particles; yet, on most occasions, doing this in a few particles will commence the new combination; and then, the caloric liberated will raise the temperature of, or cause the necessary concentration in the contiguous particles; so that the dissolution and combination of the whole mass rapidly ensue. Substances which combine the most rapidly with oxygen in their natural state, that is, without either compression, additional temperature, or the presence of a third substance added merely for the sake of commencing the chemical action, are said to have the greatest attraction for oxygen; those that combine with the most, the greatest capacity; while those that unite most closely, or so, that no other known substance will detach them, the greatest affinity. However these words are not generally restricted to these meanings, but the advanced state of the science seems to demand some restriction of this kind.

Hydrogen has undoubtedly the greatest capacity for oxygen; but we have no means of concentrating it so, that it shall have the greatest attraction; and it certainly has not the greatest affinity. For a great many of the metals will decompose water, when the hydrogen is set at liberty; the metal imbibing the oxygen and becoming an oxide, on which oxide hydrogen, however treated, has no effect. Potassium, for instance, will do at all temperatures, even as ice; so that the combustible part of that metalloid must combine a great deal more closely with

oxygen than hydrogen does. If hydrogen, therefore, united with different proportions of an unknown base constitute all the metals, and hydrogen gas be the pure element; then, the greater affinity which some metals possess for oxygen, than hydrogen possesses in the aqueous combination, must depend upon the hydrogen being much more concentrated by that unknown base, than in the aqueous combination; and, therefore, the more a substance is condensed, the more intense is its affinity, that is, the more disposed is it to part with its inherent electric fluid. On the same principle a substance becomes hot by compressure; either, the latent caloric is resuscitated, or, the original particles of the elementary substances, emit more of their inherent electric fluids: most substances by violent compressure undergo a certain change of nature, as if new chemical combinations had taken place.

The combustible fossils are a class of bodies widely differing among themselves, including both the hardest and softest mineral substances; several of them are liquid, some are soft, but the greatest number are solid. Some of them are translucent and even transparent, none possess either the opacity, brilliancy, or weight of the metals: some being lighter than water, few more than twice its weight; and such as are solid are easily broken.

2. HYDROGEN.

1 Hydrogen, 7½ Oxygen---Water.
Specific gravity ·000105. Or 100 cubic inches of gas weigh 2¼ grains.

On account of hydrogen being the principal vehicle of the positive electric fluid, we have been obliged to anticipate its most striking properties, and have now only some of its less prominent features to describe. It can only be obtained as gas, which has the least specific gravity of all ponderable substances, being about 13 times lighter than atmospheric air, and it occupies about 1500 times more space than when it is combined with oxygen in the composition of water. It is very sparingly found in the mineral kingdom, except combined with carbon and with oxygen as water; but since it forms so important a part of water, it must be one of the most abundant elements. It constitutes a principal part of all vegetables; which have the faculty of decomposing water, setting the oxygen

gas at liberty, and elaborating this element into their composition. From them, it enters the animal kingdom, and is a chief ingredient in all parts of the human body.

Hydrogen is the basis of all the inflammable gases, and is the only substance that produces flame during combustion; for there are but three simple gases, viz. oxygen, nitrogen, and hydrogen; and as these are the bases of all the other gaseous substances, hydrogen the only combustible, and flame a stream of combining gas; hence it is evident that hydrogen alone can be the cause of flame, which seems to want carbon to give it body, for singly it produces very little light. It may be drawn into the lungs, but does not afford any vital support. And though it is so very inflammable when in contact with oxygen, or is mixed with atmospheric air; yet, a lighted candle introduced into a jar filled with it is immediately extinguished. A chemist named Pilatre, having mixed nine parts of it with one of oxygen gas, by accident drew some of the mixture into his lungs along with the atmospheric air; when, his breath coming in contact with a lighted candle, the whole of that inside his lungs exploded and nearly deprived him of life. The shock was so violent that at first he imagined all his teeth were blown out.

Hydrogen gas can only be procured in a pure state by the decomposition of water. An experiment of this kind may be easily performed, by adding gradually one ounce of sulphuric acid to four ounces of water in a large phial containing a few iron filings. If a hole be neatly made through a cork that just fits the mouth of the phial, and a pipe stopper be fixed into it, and the whole be closely cemented; then, by the temperature caused by the mixture of acid and water, the iron will decompose the water, uniting with the oxygen and liberating the hydrogen gass which escapes through the bore of the stopper, and may be lighted, when it burns with a lambent blue flame. As there will be some atmospheric air in the phial, unless the decomposition be permitted to proceed a while before the cork is put in, it is advisable to wrap a cloth round it, lest exploding, it should do harm with its fragments. Again: should a glass be inverted over this flame, it will be shewn that water is reformed by the hydrogen combining with the oxygen of the atmosphere.

By a process similar to the above, air balloons are inflated with this gas: though zinc is used instead of iron, as being

more readily oxydizable, and about 6 or 8 times as much water as acid; so that, the gas is more copiously evolved, and is conducted by pipes into the orifice of the balloon.

MINERALS.—Combined with chlorine in the formation of muriatic acid, hydrogen enters into the composition of a great many mixed substances; even into some of the primitive rocks, as mica, talc and chlorite. It is also a constituent of fluoric acid, and here again occurs in mica, and of course in all the fluates. Combined with sulphur, it is found in the fœtid limestone and several other minerals. Hydrogen gas is said to be emitted from the crevices of volcanic matter, also from the crevices of a grey friable argillaceous schistose rock, surrounded by limestone mountains not far from Grenoble in France; similar circumstances occur in the road between Warrington and Chester, and also near Brozeley, Shropshire. Hydrogen is a chief ingredient in all bituminous fossils; but its principal deposit, in the mineral kingdom, is in the aqueous combination. Water exists among minerals in several different states, viz. as the water of crystallization: the primary crystals of sulphate of lime contain 21 per cent. of water, but what is called anhydrous sulphate of lime contains none. But even in some massive substances water occurs in definite proportions, the pure alkalies, potas and soda, retain even after fusion, one fifth of their weight of water; and it is occasionally inclosed in crystal and chalcedony; and is attracted in various proportions into the pores of most mineral substances.

3. NITROGEN OR AZOTE.

100 Nitrogen.	57 Oxygen	.	Nitrous oxide gas.
	114 Do.	.	Nitrous gas.
	228 Do.	.	Nitrous acid gas.
	285 Do.	.	Nitric acid gas or aquafortis.

Sp. Grav. 100 cubic inches of nitrogen or azotic gas weighs 29·55 grains.

NITROGEN is more distinguished for its neutral than its active qualities; for it will neither burn, support combustion nor animal life; and though it combines with more oxygen than any other substance, except hydrogen; yet, it holds it by a very slight affinity; and will unite in the formation of ammonia with almost as much hydrogen as oxygen itself. Dr. Priestly obtained several portions of nitrogen from repeatedly freezing the same distilled water: which circumstance has occasioned it

to be considered, by some, as a compound of hydrogen and oxygen. The experiments of Sir H. Davy are more decisive, as to its being a compound substance; but he suspects it to be of a metallic nature, or hydrogen united to an unknown base. It is only sparingly found in the mineral kingdom, but when we consider that it forms 79 per cent of atmospheric air, we must allow it to be an abundant element. It is seldom detected in vegetables, though plants are said to grow freely in its gas; but it enters largely into the composition of all animal substances, and the pure gas is said to be exhaled from the pores of the skin during insensible perspiration. In short, it is considered as the element which nature employs in converting vegetable into animal substances; and is, therefore, sometimes called the agent of animalization.

For nitrous oxide see Chap. X. s. 2. Nitrous gas is not respirable, is perfectly colourless; but on exposure to the air, it imbibes oxygen and moisture and is converted into nitrous acid. Its colour then becomes red, a little more water renders it blue; another portion, green; and another, yellow; while the vapour still continues red. When aquafortis is poured on iron filings, copper, and some other metals, some of the oxygen is imbibed, and nitrous acid is copiously evolved in red fumes. Two parts of either nitrous or nitric acid and one of muriatic form nitro-muriatic acid or aqua-regia, the true solvent of gold. This acid in its gaseous state has less specific gravity than either of its component gases.

Nitric acid gas is generally obtained by distilling two parts of nitre and one of sulphuric acid, and condensing it with water; after which some nitrous acid is separated by heat, and the remainder becomes the *aquafortis* of commerce. It is clear, of a pungent smell, very acid to the taste, and very corrosive, and with various bases forms the salts called nitrates.

Of these, nitre, nitrate of potas or saltpetre is the chief, consisting of $53\frac{1}{4}$ acid and $46\frac{3}{4}$ potas. It is principally brought from the East Indies, where, at certain seasons of the year, it is formed spontaneously on the soil. In Apulia, near Naples, are nitrate beds where the earth contains 40 per cent. of nitre; mines and beds are likewise found in various parts of the world. Nitre has often been obtained from the urine of quadrupeds, and the soil underneath dove-cotes. In Switzerland, during the late war, the farmers derived considerable profit by extracting it from the floors of their stables, and it was thus ob-

tained in England during the reign of Charles I. The French chemists in the revolutionary wars, obtained it from the plaster of old buildings; and it may be found on the outside of many old walls. It is also procured artificially by heaping together rubbish, plaster and earth, with dung and other vegetable matter under sheds; they are then moistened with animal fluids as blood, &c., and thus exposed to ferment in the air; oxygen is, therefore, obtained from the atmosphere, nitrogen from the animal matter, and potas from the vegetable substances; and, together, they form nitre, which is afterwards purified. Its chief consumption is in gunpowder, but it has various uses in the arts, as in the process of oxidizing and melting the metals.

Nitrate of lime, composed of 57·44 acid, 32 lime, 10·56 water, is found in silky efflorescences on old walls, in caverns, or on calcareous rocks in the neighbourhood of decayed vegetable matter, and in some mineral waters.

AMMONIA or the *volatile* alkali is composed of four parts nitrogen to one of hydrogen, and, when uncombined with any other substance, is in a gaseous state. It has a remarkably pungent smell, causes instant death to any animal compelled to breathe it, and is destructive of flame. It is the lightest of all substances, except the hydrogen and carburetted hydrogen gases; five measures of it being only equal to three of atmospheric air. It will therefore exhale at all temperatures; but its volatility is partly diminished by its combination with water, more so with carbonic acid, and entirely ceases when combined with the muriatic or any of the mineral acids. Water will absorb 670 times its own bulk of this gas, but the compound has less specific gravity than water itself, being only ·875. In this state it is called liquid ammonia, and as such is generally used. This alkali abounds in all animal substances while undergoing putrefaction, and is generally procured from them by dry distillation; but it is formed in various manners both by art and nature. That obtained from the horns of deer was once much esteemed and called hartshorn.

Ammonia and muriatic acid, though both of them very pungent gases, when mixed together immediately condense into a hard, ponderous, inodorous substance, known by the name of *sal-ammoniac*. This salt "acquired its name from the temple of Jupiter Ammon, it being first made in the neighbourhood of that temple. According to Pliny there were large inns in the vicinity of this famous temple, where the pilgrims lodged who

came to worship, and who usually travelled on camels. The proprietors of those stables had some contrivance for preserving and concentrating the urine of these beasts; and the salts which it produced, were afterwards sublimed in glass vessels." From Egypt was once brought as much sal-ammoniac as sufficed all Europe, but it is now manufactured in Britain, and finds its way hence to all parts of the Mediterranean. It is used in a variety of manufactures. The common smelling salt is a carbonate of ammonia consisting of 56 carbonic acid and 44 ammonia; the bi-carbonate contains double the quantity of carbonic acid, and is less pungent. Both kinds are used by the London bakers as substitutes for yeast.

MINERALS. *Sal-ammoniac* (muriate of ammonia) is found among lavas and volcanic products, also in efflorescences on certain rocks in Persia, Tartary, Bucharia and Siberia; it is also found in some waters in Tuscany and Germany, and in some English coal, especially that of Newcastle. *Sulphate of ammonia*, 40 am., 42 sul. acid, and 18 water, occurs in stalactites among the lavas of Etna, Vesuvius, and in other volcanic regions.

4. CARBON.

$$28 \text{ Carbon} \begin{cases} 36 \text{ Oxygen} & . \text{ Carbonic oxide gas.} \\ 72 \text{ Oxygen} & . \text{ Carbonic acid gas.} \end{cases}$$

Specific Gravity of Diamond 3·517.

THIS element cannot by art be obtained alone, or in a more pure state than charcoal; yet nature is supposed to have presented us with a pure specimen in the diamond. Carbon is very abundant in the mineral kingdom, especially in the calcareous rocks; and is the basis of all coal and bituminous substances. It is the principal ingredient of animal substances; and forms the solid structure of all vegetable productions, from the woody fibre of the lordly oak of the forest, to the petal of the most delicate garden flower; and is the chief ingredient in all fruits, seeds, oils, gums, resins, and perfumes.

DIAMOND is the hardest substance in nature, and is used for cutting and polishing all other precious stones. In its most perfect state, it is as clear and as pellucid as the purest water, and is distinguished from all other substances by the vivid splendor of its brightness. However, it has sometimes an accidental tinge of the metallic oxides, being of a yellowish, bluish, yellowish green, clove brown, black brown, prussian

blue, or rose red colour. Diamonds are always found in detached crystals, and the varieties of forms, in which they occur, are numerous. The structure is perfectly lamellar, yielding readily to mechanical division parallel to all the planes of the regular octohedron, which therefore is the form of the primary crystal. At a heat less than the melting point of silver, it gradually dissipates, burns, and combines with nearly the same quantity of oxygen, and forms the same quantity of carbonic acid as charcoal.

The diamond is one of the rarest substances in nature. It is supposed to have been elaborated in ochreous earth imbedded in rocks of gristone, chiefly in the East indies, the Isle of Borneo, and in Brazil; but it is mostly found in alluvial grounds and in the beds of rivers. In India the diamond mines are at the foot of a chain of mountains extending from Bengal to Cape Comorin: the chief of them are now between Golconda and Musilipatam. In Brazil they are found to the north of the river Rio Janeiro. The country is covered in all directions by grit-stone rocks, full of rounded quartzose pebbles. The hills are very numerous, and consist of grit alternating with micaceous schist; which presents an immense number of blocks composed of gritstone, imbedding round masses of quartz, and giving to the whole the appearance of a pudding-stone. The country is in general elevated, (being a primary district) and very full of streams, in which the diamonds are found. The largest diamond hitherto met with is in the possession of the Rajah of Mattan, in the island of Borneo, in which isle it was found about a century ago. It is shaped like an egg, with an indented hollow at the smaller end; is of the finest water, and weighs 367 carats, (a carat being 4 grains). The Pitt or Regent diamond, the finest of the crown jewels of France, was found at the conflux of two rivers about 20 miles from Golconda; it weighs 136 carats, and cost about £.100,000 sterling. One purchased by the Empress of Russia, in the year 1772, weighs 193 carats (779 carats according to Parkes). She is said to have paid for it 12 tons of gold, and granted a pension for life to the vender of 4000 roubles per. annum.

Charcoal is uncrystallized carbon, but is supposed to owe its colour to the retention of some salts, or potash, &c., from which it cannot be purified: yet, this extraneous matter is so small that equal weights of diamond and charcoal require the same quantity of oxygen gas to convert them into carbonic acid:

and in both cases the same quantity of oxygen gas will produce the same quantity of acid. It may be procured from any kind of wood, by burning it in close vessels, or covered with earth, only leaving holes for the pyroligneous oil or acid to escape. When this is properly done, the carbon of the wood is left exactly in the same structure that it had in the tree, and with the same external shape as the piece of wood. Charcoal is therefore very light, so porous that it may with a microscope be seen through; and, however large the piece, it may be blown through. It is black, sonorous, brittle, and destitute of both taste and smell.

If charcoal be totally excluded from the contact of oxygen, the greatest degree of heat has no effect on it; (though an American chemist, not long ago, announced that he had produced a partial fusion, and the appearance of crystallization, or the formation of diamond). Oxygen gas has no effect upon charcoal, at a lower temperature than 800 deg.: hence of all the substances in nature charcoal is the most durable. The beams of timber, at Herculaneum, were charred by the burning lava of Vessuvius almost 1800 years ago; and the charcoal is still entire. It is said that the charcoal of some corn burnt in the time of the Cæsars still exists, and that the wheat is even now distinguishable from the rye. About 40 years ago, a large quantity of stakes was found in the bed of the river Thames; which were ascertained to be the stakes placed there by the ancient Britons, to stop the progress of Julius Cæsar and his army. They had been charred half way up, and the charred ends were found entire at the heart. Beds of coal and charcoal have frequently been found, where they have evidently been deposited as landmarks by the early inhabitants of this island; and their still existing without change, shews how well they were adapted to the purpose. The ancients wrote with levigated charcoal, and accordingly such writings found in Herculaneum are still legible; it is, therefore, recommended that documents, which are to be handed down to posterity, should be done with a preparation of this kind.

Although charcoal will not form a chemical combination with oxygen at a lower temperature than 800 deg., it will nevertheless rapidly imbibe it into its pores, on which circumstance its antiseptic qualities depend. These are so great, that when putrefaction has commenced, a proper application of this substance arrests its progress. Meat that is a little tainted, so as

to smell in hot weather, may be restored by being rinsed in powdered charcoal and water. All vessels that have a bad smell, when the grosser parts of the offensive ingredients are scoured off with sand and potas, may be rendered quite sweet in the same manner. Putrid water may be restored, the bad taste of common spirit rectified, rancid oil improved, the colouring matter extracted from sirups and jellies, and impurities of several kinds may be separated from other ingredients by means of charcoal. Casks charred inside are now used to preserve water at sea, and in such vessels it is never found to be impure in the longest voyages.

CARBONIC ACID GAS, *Fixed Air* or *Choke Damp*. This is supposed to be the most abundant of all the acids; and is the heaviest of all the gases, a cubic inch weighs half a grain, so that it may be poured like water from one vessel to another. Being much heavier than atmospheric air, it lies like water at the bottoms of mines, caverns, pits, wells, and even cellars; in all which places it is frequently collected in great abundance. It cannot be breathed, and therefore the most fatal accidents have happened when persons have unwarily descended into such places. It is also abundantly generated in fermented liquors, and has often proved fatal to men working in the large porter vats in London. Burning charcoal generates large quantities of this gas, whence the fatal effects to those sleeping in close rooms where it has been incautiously introduced. Carbonate of lime, which forms a numerous class of very extensive rocks, contains about 44 per cent of this acid; and the process of burning lime is the mere expulsion of it by heat. Though to some invalids, the smoke arising from the kiln is represented as beneficial when breathed sparingly; yet, workmen, who have incautiously slept too near, have lost their lives by inhaling it. Being destructive of flame, its presence may always be detected by lowering a candle into the place suspected; and the treatment recommended for those who have inhaled it, is, the same as that in the case of drowning.

In some volcanic regions this gas is copiously evolved from the earth. Frequently, for a long time after the eruptions of Mount Vessuvius, it continues in pits and ditches, occasionally suffocating the inhabitants and destroying the vineyards. The Lake Averno emits such quantities, that birds attempting to fly over it, are suffocated and drop dead into the water. There is also in the same country a cave named *Grotto-del-Cane*, at

the bottom of which this gas is evolved; and, on account of its density, runs out at the threshold like water from a well, and therefore does not fill the whole cave, A man may generally enter with safety, the threshold not being much higher than his knee, but should a dog be put in, it is immediately suffocated. This is often done by the natives for the barbarous amusement of travellers; but the poor animal is soon withdrawn and plunged into cold water, which generally restores animation. The quantity of gas in this cave often varies, and serves to warn the inhabitants of an approaching eruption of the neighbouring volcanoes; for when it greatly abounds, an eruption of Vesuvius, or some more distant volcano is sure to follow.

This gas also enters into the composition of some of the mineral waters, as those of Pyrmount, Spa, and Seltzers. But these waters are now made artificially, and even better and stronger than they can be procured at the above places. For it is found that by very great pressure, water will imbibe two atmospheres and a half, that is, 2½ times its bulk of this gas. It then sparkles in the glass, and has a slight but pleasant acidity and briskness like fermented liquors. But indeed it is this gas which gives even them their sparkling brightness. Water charged with carbonic acid has the power of dissolving limestone. Such waters oozing through calcareous rocks, become what were once called petrifying springs. For being thus loaded with dissolved lime, when they come to day, the gas escapes, and the earth is deposited on moss or in the pores of wood and other vegetable productions, which thus become encrusted or saturated, and are then said to be petrified. Spars, or stalactites found in rocky caverns, are thus formed. Water impregnated in this manner is one kind of hard water, which becomes soft by exposure to the air, for the acid escapes and the limestone is precipitated: hence the softness of river waters though totally fed by hard water springs.

Pure or quicklime rapidly absorbs this gas; and, therefore, wherever it is present, if a little is let down and sprinkled with water, the acid is immediately imbibed, and solidified with the lime into chalk; after which, the place may be entered with safety. Hence this acid has the property of rendering some of the most caustic substances in nature perfectly mild. For when the alkalies and alkaline earths are saturated with it, they become neutral salts, being totally divested of their causticity.

CARBURETTED HYDROGEN GAS, *Heavy inflammable air* or

Fire Damp.—This is the gas used for lighting streets and houses. It is composed of carbon and hydrogen, but their proportions vary according to the process by which it is formed. One hundred cubic inches generally weigh about 20 grains. It may be generated by exposing pieces of charcoal in a glass vessel filled with hydrogen gas to the rays of the sun. But in the large way, it is procured by the dry distillation of coal.

The coal is put into close iron retorts, that are heated red hot; when, no oxygen being present, the hydrogen with a certain portion of carbon assumes the gaseous form, and escapes through long pipes into a proper receiver called the gasometer. This apparatus consists of two open vessels: the upper one inverted within the lower, which is nearly filled with water. The pipe from the retort enters the lower vessel, and its orifice is just above the surface of the water, and, of course, within the upper vessel. This latter vessel is nearly balanced by weights and a pulley; so that as the gas is generated, a little more than the atmospheric pressure, caused by the gas inside, will buoy it up; and consequently make room within for the stock of gas: its height always indicates the quantity in store. Within it, and descending through the water, is the pipe communicating with the lamps; and the water serves as an effectual lute.—Besides the main pipe from the retort, there is another furnished with a stop cock, that is opened at the commencement of the process; and through which escapes a portion of carbonic acid gas, and water saturated with ammonia, formed from the atmospheric air in the retort, and the casual oxygen and nitrogen found in the coal. The pipe between the retort and the gasometer is always purposely long and is arched, that the gas may cool and have its impurities separated, such as coal oil and tar; a considerable portion of which always escapes with the gas, and which consists of carbon and hydrogen that have not had sufficient heat to give them the gaseous form. The gas is sometimes made to pass through lime water, which further purifies it. In this manner the whole of the hydrogen is driven off with part of the carbon, the remaining carbon, called the coke, is left in the retort, and is worth as much as the original coal. One pound of coal generally yields about 24 gallons of gas, or somewhat less than 6 ounces by weight, and near 2 oz. of oil and tar. Hence it appears, that about 2¼ lbs. of coal yield as much light as one pound of oil or tallow.

It is this gas which has caused so much destruction of hu-

man life in the coal mines. Being evolved from the fissures in the coal beds, whenever the atmospheric air becomes charged with one thirteenth of this gas, it is highly inflammable, and if entered by a lighted candle, immediately explodes. "It prevails more or less in all coal mines, and is the most terrible and destructive evil the miner has to contend with. It is supposed in these situations to be generated by the contact of water and pyrites, though it is the most abundant in the dry seams, out of which it issues with a hissing noise: the places evolving it, in this manner, have their orifice fringed with a thin pellucid film and are called *blowers*. Sometimes, especially where the strata are shattered, it issues out of fissures and cavities in considerable quantities, and explodes at the workmen's candles. But, when, either from the fallings of stoppings in the wastes, or by neglect of shutting some of the trap-doors, the current of atmospheric air has been for some time diverted from its proper course, the element has been suffered to accumulate, then, if incautiously ignited by the candle of the person that first visits the inflammable repository, effects of a volcanic nature are produced. The subterraneous lightning scorches and mangles the workmen exposed to its fury; sweeps down its long galleries in one common torrent of destruction, limbs of men and horses, doors, brattices, workmen's tools, and coal dust; all which it ejects through the shafts accompanied with thick columns of smoke and fire. The noise of the explosion resembles that of a distant park of artillery, and the echo it produces is like the reverberation of thunder in the higher regions of the air.

"At Lambton colliery on the 22nd of August, 1766, the workmen, to the number of an hundred, had just left work, and three masons, with as many labourers, were left to build up a partition to secure the coals from taking fire by the lamp; when the said lamp, being let down at the request of the masons to rarefy the air, the latter in an instant took fire with a terrible explosion, and made its way up the pit destroying men, horses, and all in its passage. The noise of the explosion was heard above three miles round, and the flash was as visible as a flash of lightning. The men below were driven by the force up through the shaft or great tube, like balls out of a cannon, and every thing that resisted shared the same fate. The neighbourhood being alarmed, collected itself in order to give assistance, but found only heads, arms and legs thrown

out to a great distance from the mouths of the pits. The ground for acres was strewed with timber, coals, &c. All the partitions, trap doors, wood props and linings were swept away, together with the engine for drawing up the coals, and all the apparatus.

"Workmen, who have escaped the fury of these blasts, describe them as instantaneously preceded by a strong sudden wind; and as afflicting the head with pains as if it were pierced with arrows; and even in cases where the person sustains little injury from the fire, as causing, in the hands and face and other parts of the body, a hot scorching pain. They who have presence of mind to throw themselves flat on their faces are seldom injured, especially where there is water; but if they be left in a vacuum or where choke-damp (carbonic acid) prevails they soon suffocate." See the Picture of Newcastle-upon-Tyne.

Sir H. Davy's safety lamp, it is hoped, will in future prevent many such calamities. The principle on which this lamp is constructed is very simple. That great philosopher is said to have accidentally discovered, that flame will not pass through very small apertures in metallic substances. And therefore he inclosed a lamp in a fine metallic gauze or net-work, so as to emit light but not flame and heat. A piece of strong wire is so contrived that the workman can trim his lamp without opening it. But the inventor afterwards made a very great improvement, by suspending a piece of platina wire over the flame inside the net-work. When the workman enters the gas, which alone is destructive of flame, his lamp goes out; but the platina, by its violent affinity for hydrogen, becomes immediately red hot, and affords light sufficient for him to grope his way out to pure air, when the heat of the wire re-kindles the flame of the lamp. The great inconvenience attending this lamp, is, its not permitting sufficient light to pass through the wire gause: hence, it is supposed that workmen have been sometimes tempted to remove the gause for the purpose of searching for lost articles, and thus many fatal explosions have occurred where this lamp has been used. A contrivance has lately been announced, of constructing three or four inches of the lower part of the lamp with plates of mica, which will endure the heat of the flame, will not easily break by accidents, and will permit light to pass equally with glass.—A consummation devoutly to be wished!

Carburetted hydrogen gas is evolved from stagnant water

when the summer's sun shines hot upon it, and may be collected by an inverted bottle at the surface. In hot climates, it is frequently emitted from swampy grounds; and in volcanic districts, it sometimes issues from fissures of the earth, which, being once lighted, will burn as long as the emission continues. Such fires are not unfrequent in Italy, and the famous Chimera of the ancients is of this description. Near the summit of a hill is a rock, in which is a small aperture, whence a stream of this gas issues; and having been once ignited, by some means or other, is supposed to have been thus burning like a lamp for thousands of years. It was represented as a monster by the poets, with the head and breast of a lion, the middle part of a goat, and the tail of a serpent, also as continually vomiting out flames. For upwards of two thousand years, the situation of this phenomenon was not known, but it was casually discovered a few years ago, in a mountain in Asia Minor, hid in the thick recesses of primæval woods, the suitable habitation of lions, goats and serpents. Near Baku in Persia this gas is evolved from the ground. On or near the spot is a temple, into which it is conducted by pipes; and being once ignited, and a continued supply obtained from the ground, it never goes out. Here the Persees or Fireworshippers pay their devotions, and venerate the flame as a portion of "the eternal and universal Fire".

MINERALS. *Mineral Carbon*, or *Charcoal*, consists of carbon with a small quantity of earth and iron, has often a wood-like texture, and occurs in thin layers among common coal. *Plumbago, graphite* or *black-lead*, contains about nine parts carbon to one of iron. It occurs of a lamellar texture in masses, in kidney shaped lumps, or disseminated in rocks, and sometimes crystallized in regular six sided prisms, of which the summits are striated parallel with their edges. It belongs chiefly to primary rocks. The most esteemed is that found in Borrowdale, Cumberland, in a schistose rock traversed by veins of quartz. It has also been found passing into a kind of coal of a columnar form in Ayrshire, and is also met with in mica slate in Aberdeenshire, In Bavaria it occurs in granite, and is occasionally found in all the other primary rocks. *Anthracite*, carbon 72·05, silica 13·9, alumina 3,29, oxide of iron 3·47, occurs in primary, transition, and trap rocks, both massive, slaty and columnar. That of *Kilkenny* has a fibrous texture, with occasionally all the characters of well burnt charcoal. In Scotland it is called

Blind Coal, in Staffordshire *Stone Coal*, and in Wales, *Culm*. It is of an iron-black colour, of metallic lustre, burns without flame or odour, and leaves a whitish ash. Carbon, also uncombined with hydrogen, enters in small quantities into the composition of a few other minerals, as from 1 to 11 in clayslate the lowest of the transition rocks and rotten stone 10 per cent. It is also found in compact manganese, semi-opal, and hepatite; and combined with oxygen, abounds in all common limestones.

The *Bituminous* minerals, or those wherein the carbon is combined with hydrogen, are, including the different kinds of coal, about fifteen in number. *Mineral Oil*, includes *Naptha* and *Petroleum;* the former consists of 87·21 carbon and 12·97 hydrogen. The most copious springs of naptha are in the coasts of the Caspian Sea. The city of Genoa is lighted with naptha from a spring in the state of Parma. It occurs in several other places, but is sometimes confounded with *Petroleum* which contains some oxygen, imbibed from the atmosphere. It occurs in most of the coal districts. *Bitumen* or *Mineral Pitch* has three varieties, *earthy* or *maltha*, *elastic*, and *compact* bitumen or *Asphalt*. The first and second kinds seem to be petroleum with some earthy matter, but *asphalt* contains more carbon. In the isle of Trinidad is a lake three miles in circumference, and of an unknown depth entirely of this substance,—porcelain jasper occurs near it. Asphalt occurs in various other parts of the world, but the Lake Asphaltum or Dead Sea, is the most noted place: this leaves an earthy residium containing the following muriates, viz. of lime 3·792, of magnesia 10·1, of soda 10·676, and a little sulphate of lime. The water is saturated with it, and lumps are sometimes found floating on the surface, but it is also found in the waters of Jordan. Its specific gravity is from 1 to 1·6.

COAL.	Newcastle or Caking	75·28 Car.	4·18 Hy.	15·96 Nit.	4·58 Oxy.
	Splint from Glasgow	75· ..	6·25 ..	6·25 ..	12·5 ..
	Cherry (Glas. & Staff.)	74·45 ..	12·4 ..	10.22 ..	2·93 ..
	Cannel	64·72 ..	21·56 ..	10·72 ..	
	Jet	76· ..	22. Bitum.	2 Earths.	
	Brown (Bovey, &c.)	45· ..	30. Pyroligneous acid, the remainder Carburetted Hydrogen, and Carbonic acid gas: nearly the same as wood. See Coal Formations, Chap. XV.		

The other carbonaceous minerals, are, *Dysodile*, *Amber* and *fossil Copal* which will be mentioned hereafter. Also *Hatchetine* which occurs in iron stone at Merthyr Tydvil. *Mellite* con-

taining a peculiar acid called Mellitic acid; and *Retinasphaltum* consisting of 55 resin, 42 asphalt, 3 earth. It occurs in the Bovey coal, and along with the mineral charcoal in Staffordshire. All the carbonaceous minerals may, perhaps, be considered as derived from coal; and as coal is supposed to have had a vegetable origin, and vegetables receive their carbon from the decomposition of carbonic acid; so, this last substance, which is the most abundant of all the mineral acids, forming nearly a half of carbonate of lime the fertilizer of soils, may be considered the great mineral parent of all these fossils.

5. BORON.

27 Boron, 73 Oxygen---Boracic acid.

THIS substance, on account of its capacity for oxygen, claims the next place in our list of simple combustibles. It is an opaque, dark-olive coloured, infusible powder, insoluble in water; and burns, when heated in atmospheric air, with a red light;—but the acid gives a green colour to the flame of burning bodies.

It has but one combination with oxygen, and only thus united does it combine with other substances. In fact, the acid is the only state in which it can be procured without the galvanic apparatus. It is slightly acid and rather bitter to the taste; is fusible at a strong heat; and, when well crystallized, is in the form of thin scales with the appearance of solid white glass; is unalterable in the air, but dissolves slowly in cold water and rapidly in hot. It has the property of dissolving all stones, and is therefore very useful for their analysis. In short, without it some could not be analyzed; for, the great difficulty is to bring them into solution, after which the ingredients are easily ascertained by the chemical tests. It is sometimes used in the composition of artificial precious stones.

MINERALS. *Native Acid* contains 11 per cent. of ferruginous sulphate of magnesia, and 3 of sulphate of lime.

Borax or *Tincal* 36 acid, 17 soda, 47 water.

Boracite 83·4 acid, 16·6 magnesia.

Datholite 21·67 acid, 34 lime, 37·66 silex, 5·5 water.

Botryolite 13·5 acid, 39·5 lime, 36 silex, 6·5 water, 1 ox. of iron.

The acid is found dissolved in springs and lakes, as well as solid in the lavas of the volcanic districts, of Italy and Thibet. Borax, in the rough state called tincal, is obtained from the

water of a lake in Thibet; but is found in several other places as Ceylon, Tartary, Transylvania, Lower Saxony and Potosi. Boracite is found in a rock of gypsum, Honover; and also in Thibet. The last two minerals occur in primitive rocks in Norway.

6. SULPHUR OR BRIMSTONE.

1 Sulphur	1	Oxygen---Sulphureous Acid	
	$1\frac{1}{2}$	ditto	Sulphuric Acid

Specific gravity, 1·99.

Sulphur is a pale yellow, opaque, and solid substance; very brittle, insoluble in water, a non-conductor of electricity, very inflammable, has the property of stopping fermentation in wine, and is capable of being sublimed in close vessels, when it is deposited in fine powder called *flowers* of sulphur. It is extensively diffused, being found in all parts of the world, but chiefly in volcanic districts; the larger part of metallic ores are combined with it; and it unites with all the other simple combustibles, though not in so large a proportion as when they are combined by nature. From the mineral, it enters the vegetable kingdom, having been detected in the cress, horse-raddish, garlic, and many other plants. It thence passes into the animal kingdom, and occurs in almost all parts of the body. It is what stains the spoon in a hot egg; but it principally manifests itself during putrefaction, combined with hydrogen, forming sulphuretted hydrogen gas; which is the cause of that disagreeable and unwholsome stench arising from putrid eggs and house drains.

Sulphurous acid gas is the fumes arising from a burning match, and is of a most penetrating smell. It is invisible, as are nearly all the gases. It abounds in the environs of volcanoes, vast quantities being evolved during an eruption; and is what suffocated Pliny in that of Vessuvius, which overthrew Herculaneum in the year 79. It has the property of discharging some colours, as may be proved by holding a red rose in the fumes of a match, when it soon becomes white. Iron molds in linen or cotton, if previously moistened with water, may be so removed. Straw hats are bleeched by being submitted to it in closed vessels; and silks, dyed lilac with archil, are rendered a flesh colour.

Sulphuric acid is destitute of smell and colour, has a strong acid taste, and is very corrosive. It was once obtained from green vitriol (sulphate of iron,) whence it is commonly called oil of vitriol or vitriolic acid. It is also in a gaseous state; but having a great affinity for water, the manufacturer condenses it therewith:—hence, the acid of commerce is always in a liquid state. Four pounds of this liquid acid well concentrated, mixed with one of water, will raise the temperature to 300deg. The liquid acid will freeze much sooner than water, and is nearly double its weight. It will combine with a great many substances, but its chief affinity is for barytes. For whatever sulphates, being dissolved, are mixed with barytes, also dissolved, sulphate of barytes will be instantly formed and precipitated. Every 100 grains of which, after having been submitted to an intense heat, consist of 66 barytes and 34 dry sulphuric acid. It is sometimes called ponderous spar. This acid has been found in a concrete state in some volcanic craters.

MINERALS. *Native sulphur* is found in veins of granite in Suabia, in mica slate in Hungary and Peru, in Swinestone near Gibralta in Spain, and in many places with calcareous spar and gypsum of the salt deposit, generally in beds. It is of various shades of yellow, from pale to deep orange, and sometimes has a tinge of green. It occurs massive, disseminated, investing other minerals, and crystallized in octohedrons. *Volcanic* sulphur differs little from the above, but is generally found in the craters of volcanoes. Solfatara near Naples, a kind of sunken plain surrounded by rocks, is regarded as an ancient volcano, and is the most extensive deposit of sulphur known of: it has nearly supplied Europe for 2000 years.

Martial pyrites is a sulphuret of iron, 52 sul. and 48 iron. It is sometimes crystallized both in tubes and octohedrons, and some specimens are so beautiful that they have been mistaken for gold. It is found in almost all kinds of rocks, but that best known occurs in coal, especially the Newcastle. It is sometimes collected for the purpose of manufacturing sulphate of iron. The pieces are merely thrown into heaps, and exposed to the air and moisture, when the sulphuret by the absorption of oxygen is converted into a sulphate, (copperas) chiefly used in dying black. The most abundant sulphate is that of lime (gypsum) 46 sul. acid, 33 lime, 21 water. When burnt and reduced to powder it has the peculiar property of solidifying

with water; so that in a few minutes a mixture of 79 gypsum and 21 water becomes hard. It occurs crystallized, fibrous, of a granular texture; compact and earthy. The following are varieties of this mineral called *anhydrous gypsum* (without water).

Muriacite. 60 sul. acid, 40 lime, with occasionally 1 of muriate of soda.
Granular. 55 sul. acid, 41·75 lime, 1 muriate of soda.
Fibrous and *compact.* 56 50 sul. acid, 42 lime, 0·25 muriate of soda.
Siliciferous. 92 sulphate of lime, 8 silica.

Epsom Salts is a sulphate of magnesia, containing 67 sul. acid, 33 magnesia. It is found native on the surface of the soil in some parts of Spain, and also in the quicksilver mines of Idria; but the principal part of that used in England, is obtained by means of sulphuric acid from the magnesian limestone. *Glauber's Salts* is a sulphate of soda, 24½ sul. acid, 19½ soda, 56 water of crystallization. A native combination of these two salts occurs crystallized at Sedlitz. They also occur in sea water and several spas. The mineral waters of Godstone, Surry, contain 20 grains per pint of sulphate of soda; and those of Cheltenham from 10 to 23½. Sulphate of ammonia is found among the lavas of Etna and Vessuvius.

Water oozing through rocks containing sulphate of lime, becomes what is called *hard* water, which is neither fit for washing nor any other domestic purpose. When used in washing, the soap being composed of oil or tallow, and potas or soda, a double decomposition takes place. The acid seizes the alkali, and sulphate of potas or soda is formed, which remains dissolved in the water; while the lime combines with the oil or tallow and swims like curds on the top. However such water may be rendered soft by adding to it, about 24 hours before it is used, a very small quantity of carbonate of potas or soda; when a double decomposition takes place, and sulphate of soda or potas and carbonate of lime are formed: the latter is precipitated to the bottom, so that the soap is unaffected.

7. PHOSPHORUS.

20 Phosphorus { 15 Oxygen . Phosphorous acid.
22½ Do. . Phosphoric acid.

Specific Gravity 1·75.

PHOSPHORUS is a peculiar substance, chiefly distinguished for its luminous and inflammable qualities. It is of a poisonous

nature when taken alone, but is sparingly used in medicine. It is as soft as, and more ductile than wax; insoluble in water, and of a flesh red or a yellowish semitransparent colour. It melts at 90 deg., is luminous in the dark at all temperatures, and is so inflammable that it requires to be kept in water; and even in water will take fire at a temperature of 148 deg. It burns with a brilliant white flame, and is converted into phosphoric acid, which has the form of light locks of a snowy white colour, and a very strong acid taste; but by exposure to the air it attracts moisture and becomes liquid. It is mostly found in the acid state in all its natural combinations. The ores of lead, manganese, and copper often contain from 18 to 31 per cent. of this acid; it also contaminates many of the iron ores, and is found combined with lime in the proportion of 50 per cent., but it is not an abundant substance. From the soil it enters the vegetable kingdom, and is found in various substances, but especially in the ferina of wheat. It has been calculated that a person who eats a pound of wheat flour a day, swallows 3 lbs 6 oz. 4 dr. 44 grs. of phosphate of lime in a year. It occurs in almost all animal substances, but especially in bone; from which by a long and tedious process it has hitherto been obtained. Fish bones contain the most; and it is what gives drying haddocks the luminous appearance by night.

Phosphuretted hydrogen gas is the most inflammable substance in nature; and as it is known to be evolved from bogs, decaying vegetables, and putrefying animal substances, and inflammable at the common atmospheric temperature, it is supposed to form the *ignis fatuus*, or, *Will o' the wisp*. In Spain these lights are very common; and in hot climates, where they are frequently not particular in making graves sufficiently deep, this gas is abundantly evolved from recent inhumations, and by night appears as a pillar of light over the grave. The ignis fatuus is, also, frequently seen hovering in a faint blue flame in the burying grounds of England: hence, perhaps, the notion which has prevailed in some countries, that the soul of the departed hovers in the form of a small faint blue flame near the head of the mouldering body.

Several animals, among which is the glow-worm, have the power of exhibiting luminous substances. Several species of zoophites, found in the sea, are phosphorescent; but of these the *Pyrosoma Atlanticum*, found near the equator, is the most wonderful. These creatures vary in size from three to seven

inches in length, appear at a great depth like red hot cannon balls, and at the surface like glowing cylinders of red hot iron. They are in immense shoals; and, consequently give to the sea the appearance of liquid fire. The colour of the animal is an opal yellow mixed with green; but by the slightest irritation, it instantly inflames, and becomes like red hot iron of a brilliant brightness. As the animal loses its powers, it presents a number of successive tints, as red, aurora, orange, green and azure blue,—all extremely agreeable, and the last exceedingly lively and pure. The external surface is bristled with thick oblong tubercles, shining like so many diamonds, and which communicate internally with little oblong narrow glands,—and these seem to be the organs of its wonderful powers.—No satisfactory explanation has been given of these phenomena. It is ascertained that the substance, which emits the light, does not contain phosphorous; is uninflammable, and suffers no ascertainable diminution during the illuminating operation. Electricity and heat have no other effect than what may be expected from animal irritation:—yet, doubtless, it is an electric phenomenon, occasioned perhaps by a power akin to that possessed by the torpedo.

MINERALS.—*Phosphate of lime*, massive; *Phosphorite*, in six sided prisms, terminated by one or more planes; *Apatite*, six sided pyramids; *Asparagus Stone*, consisting of phos. acid 45·72, and lime 54·28; and Moroxite, from Norway, are all varieties: they chiefly occur in primary districts, but in Spain is a whole mountain of phosphate of lime. There are several fossils, which will emit light when slightly rubbed, and must therefore either contain phosphorus or be highly electric.

8. FLUORINE.

THIS substance seems more a supporter of combustion than a combustible; but which of the electric fluids is predominant in it, is not yet sufficiently known so as to determine its classification. It is the basis of Fluoric acid, supposed to be a combination of this substance and hydrogen, yet fluorine will burn when heated in oxygen gas. It has not been exhibited in a separate state, but its colour seems to be a chocolate.

Fluoric acid is chiefly found in fluate of lime, it also accurs in the enamel of human teeth, and in ivory. It has partly the smell of muriatic acid, and will saturate more of any substance

it unites with than any other of the acids. It is chiefly obtained by pouring sulphuric acid upon fluate of lime, applying heat; when, the sulphuric having a stronger affinity for lime, the fluoric is set at liberty, collected and condensed in water.

It cannot be obtained pure as gas, but, its chief affinity being for silica, of which earth it will saturate almost twice its own weight, it therewith assumes the gaseous state. And as this gas has a strong affinity for hydrogen or animal moisture, if a small animal be put into it, it becomes immediately encrusted, when it has the appearance of a real petrifaction. On account of this affinity for silica, it cannot be kept in glass bottles; but is generally preserved in lead or platina. However this property renders it very useful for etching on glass, on which beautiful drawings are made, as imperishable as the glass itself. This is done by covering the glass with wax, and then cutting out the figures; after which it is exposed to the fumes of the acid, when the lines are opaque and dark, but should the liquid acid be used, the lines are transparent. However it should be used on all occasions with great caution, for it rapidly corrodes the skin and produces tedious wounds. To obviate the danger of this, complete apparatus are sold in London, fitted up for Ladies' drawing rooms.

MINERALS.—*Fluor* or *fluate of lime*, 32.25 fluoric acid, 67·75 lime, is found crystallized, nodular, compact and earthy. The crystals have a lamellar structure, and some of them exhibit a number of planes and many varieties of form, but the octohedron is considered as the primary crystal. Fluor is occasionally transparent, also white, grey, and of various shades of blue, green, red, yellow, purple, and almost black. The most prevailing colour is deep purple, but by exposure to the sun and other temperatures, its tints can be variegated almost at pleasure. It is found only in metallic veins, and is very abundant in all the tin, copper and lead mines of England. Those of the north produce the most transparent; but Devonshire yields the greatest variety of forms, some crystals exhibiting above 300 faces. In Cornwall it generally forms the great body of the vein, and in Derbyshire it is so abundant as to be called *Derbyshire Spar*. It occurs in many of the German mines. Mont St. Gothard affords rose red coloured octohedrons. There are several other minerals, which contain a small portion of fluoric acid; As *Mica* 1·12 per cent., *Cryolite* 47 fluoric acid and water. *Yttrocerite* 24·46. It also occurs in the

Amblygonite, and in the ores of Cerium. The *Topaz* contains about 5 per cent; and the *Scorlite*, *Pycnite*, or *Schorlaceous beryl*, about 6.

9. SELENIUM.

THIS is a recently discovered substance; it combines with oxygen and forms selenic acid; but it is doubted whether it should be included among the metalloids. It is of a grey colour, melts at a temperature above boiling water, when cooling is ductile, may be kneaded between the fingers and drawn out into fine threads, possesses a strong metallic lustre, and is somewhat translucent. When cooled slowly, it has a granular fracture and resembles cobalt. It sublimates in close vessels at a temperature a little below redness, and evaporates before the blow-pipe, when its most striking feature is displayed; viz. a strong smell of horse-raddish :—about a sixteenth part of a grain will fill a large apartment.

MINERALS. It occurs in the martial pyrites and sulphur of Fahlun, Sweden; and was first discoved in the reddish masses, chiefly sulphur, deposited in the chambers for making suphuric acid. But a mineral containing 38·93 silver, 23.05 copper, 26 selenium and 8·9 other substances has been discovered in the same country, accompanied also by a seleniuret of copper.

CHAP. XII.

The Metalloids.

1. REMARKS.

The metals are a numerous class of bodies, and form a very considerable portion of the earth's substance, indeed, since Sir H. Davy discovered that all rocks or stones are mere metallic oxides, we may consider them as the solid structure or frame work of the globe. They are all nearly allied to each other, being apparently compounded of both positive and negative elements; but the former so much prevail, that they are all decisively to be classed among the simple combustibles. They all combine with oxygen, though each under some circumstance peculiar to itself, and during such combination are capable of producing much light and heat. As we suppose the electric fluids to be the grand instrumental movers of nature, and the quantity of combining oxygen with the intimacy of its union, as the nearest approach to a knowledge of the inherent quantity of those fluids, we might in conformity to this theory make the capacity of each metal for oxygen the foundation of our classification; but as Parkes in his "Chemical Catechism," (a book that cannot be too much recommended to all who would become acquainted with the beautiful science of chemistry, and from which book the following account of the metals is principally taken) has made the mode of combination, and the properties of the compound the data for his division, we shall follow his

example. And as there is a wide distinction between these combinations,—the affinity of some for oxygen being so great, that they cannot be examined in contact with atmospheric air without in the mean time disappearing, being converted into oxides; and as the specific gravity of these is also not above a sixth part of the lightest of the others; we shall make these circumstances the foundation of a division of the metals into two chapters, calling those that have this violent affinity for oxygen, and slight specific gravity, "Metalloids."

On account of this great affinity, these metalline substances are never found otherwise than combined with oxygen. They, or even the earths silica, alumine, lime and magnesia, form the basis of nine-tenths of the rocks, stones, or soils that come under our daily observation; and even constitute the prop-work of the human frame itself, since bones are phosphate of lime and lime is a metallic oxide. Many of them are found, though but sparingly, in the vegetable kingdom. But there is another circumstance worthy of being mentioned respecting the metalloids. They are all the bases of such substances as were, before the researches of Sir H. Davy, considered as simple or indecompoundable; and to that great philosopher alone, and the galvanic apparatus of the Surry Institution, we are indebted for a knowledge of them. They are subdivided into three classes, viz. 1. those which by their union with oxygen constitute the alkalies. 2. The bases of the alkaline earths. And 3. Simple earths.

The *first* class comprehends the bases of the fixed alkalies, potas, soda, and lithia; viz. potassium, sodium, and lithium, They have a very great affinity for oxygen, but not so great as those which compose the other two classes. They were first discovered by placing a piece of the alkali, a little moistened with the breath, upon an insulated disc of platina, which was in contact with the negative wire of the powerful galvanic apparatus of the Surry Institution while in intense action:—the positive wire being in contact with the top of the alkali. A most violent action soon commenced. The alkali was fused at each point of contact, and the metallic base was given out in small globules. Since this, the French chemists have obtained these metalloids in a larger way, by keeping the alkalies a long time in fusion with intensely hot iron.

The *second class.* Encouraged by his success on the alkalies, he instituted a set of experiments upon the alkaline earths, lime,

magnesia, barytes and strontites. The task with these was more difficult and he could only obtain amalgams. A portion of each earth was kneaded into a paste, and formed into a ball with a small hole at the top sufficient to hold a globule of mercury. In this case the mercury was in contact with the negative wire, and the platina with the positive. By this means he obtained various results, but such as enabled him to determine that the real nature of the bases is metallic; and he named each from its earth, *calcium*, *magnesium*, *barium*, and *strontium*.

His experiments on the *third* class, or simple earths, silica, alumina, zirconia, glucina, and ittria, were not so successful; and the results, with respect to their having metallic bases, were less decisive; yet such appearances were, generally, indicated, except in silica, as warrant the conclusion that they are metalline substances combined with oxygen: their names are therefore *silicium*, *alumium*, *zirconium*, *glucinum*, and *ittrium*. What is known of the recently discovered earth "thorina" was mentioned Chap. X. s. 7. Though it has not been decomposed, its base is included among the metalloids.

2. POTASSIUM.

100 Potassium.	10 Oxygen	.	Grey Oxide
	20 Do.	.	White Oxide or Potas
	40 Do.	.	Orange Oxide

Specific Gravity ·865.

POTASSIUM may be considered as one of the wonders of the world, since it has the property of setting water, and even ice on fire. It has also less specific gravity than water, and is, therefore, with the exception of sodium, the only metal that will swim in water. Its colour is perfectly white, with the lustre of polished silver. It is solid at the usual temperature of the atmosphere, becomes soft and malleable with the heat of the hand, melts at 150 degrees, and evaporates before it arrives at a red heat. It decomposes water so rapidly, by its union with the oxygen, that even when thrown on ice, it will burst into a flame, the combination of the oxygen and positive base of the metal evolving sufficient caloric to commence combustion in the liberated hydrogen gas; and this process goes on till all the metal is converted into potas, which remains in the hole made in the ice. If a little is placed on turmeric paper, it will run about as if in search of moisture, leaving a deep coloured

train behind. On account of this great attraction for oxygen it can only be preserved in a metallic state in pure naphtha, a liquid that contains no oxygen. But this affinity makes it a very powerful and useful agent in the hands of the chemist, as by its means he can detach water from very highly rectified alcohol and ether, and oxygen from any other substance. It will combine by pressure with phosphorus; and, also, with double its bulk of mercury; in both cases, producing considerable heat. The amalgam is solid at the common atmospheric temperature, but the potassium still attracts oxygen, and is converted into potas; also if put in water it produces a hissing noise, and in both cases the quicksilver is set free.—It is not an abundant substance, and only occurs in nature in the state of potas, but is found in the mineral, vegetable and animal kingdoms, though very sparingly in the last.

Potas is found in almost all kinds of plants, especially in the buds or young leaves; but exists also in some kinds of wood. From this source only is all the potas of commerce derived; and consequently all the pure specimens of the metal that have yet been exhibited. When vegetables are a long time steeped in water, all the potas is extracted, but the usual method of procuring it, is, to burn them, generally wood, and extract the alkali from the ashes. Hence this alkali has been sometimes called the vegetable alkali; and as the vegetable substances were once burnt in large pots made for the purpose, it was thence called *potash*. The ashes are mixed with lime, put into large vats, and water is poured over them. After standing a few days, the water is drained off at the bottom, holding in solution the potash. It is then boiled down till it is of a fine claret colour; after which it is cooled and becomes solid, having the appearance of a grey stone. But in this state it is combined with a large quantity of carbonic acid; and, being submitted to an intense heat in a reverberatory furnace, becomes more pure and caustic, assumes a bluish colour, and is then called *pearlash*. It is principally brought from Russia and America where wood is of little value. One thousand pounds of ashes of the maple tree, will yield 110lbs of potash; the same weight of oak ashes 111; elm 166; hickory 180; beech 219 pounds. It has various uses both in the arts and medicine.

MINERALS.—Potash occurs in felspar and mica, two of the constituents of granite the lowest or oldest of the primary rocks;

and as the other rocks, taken as a whole, consist nearly of the same elements, and perhaps nearly in the same proportions, we must expect the same proportion of potas to continue through the whole series of the secondary rocks. But as the other elementary ingredients of granite are blended or separated in every possible way, so potas is found very irregularly distributed through the mineral kingdom, while a great deal of it is employed in the vegetable kingdom. As most of the secondary rocks have been deposited from water, and potash has a greater affinity for that fluid than most of the other materials, it would remain suspended, while the others were deposited; hence, we seldom find it in the regularly stratified rocks—but in the nitre beds, in soils, and in crystalline compounds formed mostly from aqueous depositions in rents or cavities in the bosom of other rocks. Common feldspar contains 13 per cent.; compact feldspar 5·5; blue feldspar 0·25; mica 8·39; scaly talc or nachrite 17·5; talc 2·75; chlorite 2, muriate of potas or soda; native alum 0·25; alum-stone 10·021; nitre 46¼; green earth 10·; soap-stone 0·75; agalmatolite 7·; these are found in masses or strata; some are connected with the primary, some are transition, and others are secondary. Pumice 3·, potas and soda; obsidian 6·; these with perhaps pearl-stone 5·50, are volcanic products; and the remainder are inclosed crystals. Leucite 21·35; andalucite 8; bucholzite 1·5; apophyllite 4; haüyne 11; gieseckite 6·2; adularia or moonstone (feldspar) 14; schorl 6·; killinite 5·; common jade or nephrite 8·5; saussurite 0·25; lepidolite 4·186; meionite 1·812; pollyhallite 27·7 sulphate. The following contain potas and soda, fettstein 16·5; scapolite 0·5; chabasie 9·34; gabronite 17·25; tourmaline 2·42. Potas is said to occur in the oolite.

3. SODIUM.

100 Sodium. $\left\{\begin{array}{l}\text{.. Oxygen not known, Grey Oxide.}\\ \text{34·5 Oxygen . White Oxide or Soda.}\\ \text{.. Oxygen not known, Orange Oxide.}\end{array}\right.$

Specific Gravity ·935.

This metalloid has the whiteness and lustre of silver; and is so exceedingly malleable, that two pieces may be welded in the hand. It is somewhat similar to potassium, yet all their individual properties are very distinct. Its specific gravity is greater, though less than water; it is less fusible; nor will it

dissolve like that metalloid in hydrogen gas; and its affinity for oxygen is considerably less. When exposed to the air, it gradually absorbs oxygen, till it is converted into soda; but will not inflame like potassium when thrown on water, though its action, as indicated by its hissing noise, is very energetic. If heated and thrown into oxygen gas, it burns with great splendor, but it seems to have a stronger affinity for chlorine than oxygen, and combined with chlorine, it is chiefly found in nature. It melts at 180deg., and evaporates at a strong red heat.

Sodium is, perhaps, not a more abundant substance than potassium, its great repository is rock salt (muriate of soda) or in the waters of the ocean, whence it enters the vegetable kingdom, but is only found in marine plants, or such as grow on salt grounds. These plants seem to have the power of decomposing salt, and of taking the sodium, perhaps combined with oxygen or as soda, into their composition, and of evaporating the chlorine or muriatic acid. They are therefore collected and burnt into kelp. Thousands of people in the highlands of Scotland, in various parts of England, in Ireland, the island of Sicily, and especially in Spain, derive their subsistence from this source; and hence we have the principal of the soda of commerce. That imported from Spain is called *barilla*; and is principally procured from a plant that grows on inland salt grounds, called salsola-soda or salwort.

Soda occurs in all the animal fluids, and is found to perform a most important office in the animal economy; for to its presence the bile owes its acrine property. "In all other cases," says Parkes, "where this alkali is found, it is mild or neutralized, and its caustic qualities must be developed by art, but in the bile it is in a state of causticity." Contrivance is the impress stamped on Nature's works!

The chief consumption of soda is in the manufacture of soap; which is composed of about 3 portions of soda to 4 of tallow. The hard yellow soap has about one portion of rosin mixed with the tallow, which renders the soap more detersive, and enables the maker to sell it cheaper. This soap ought to be very firm; when it is not so, it contains a large portion of water, which considerably adds to its weight, and thus the consumer is defrauded. Sometimes a little train oil is used with the tallow; and soft soap is entirely composed of this oil and potas.—The principal on which soap acts is this: the alkalies have a great

affinity for all animal substances, grease or vegetable oils, and it being an oil that gives the colour to the unbleached linen; hence the alkali mixes with it, neutralizes or saponifies it, and the water dislodges it from the fibres of the thread. The tallow of the soap serves merely to restrain these caustic qualities, which could not otherwise, in domestic purposes, be rendered sufficiently dilute. But for bleeching, carbonate of soda is used. Indeed for all such purposes, soda, as having a less affinity for oxygen than potas, is generally preferred.

MINERALS.—Besides those minerals mentioned in the last article wherein soda occurs with potas, also muriate of soda and borax, it likewise occurs in the following. Clinkstone 8·1 per cent.; pitchstone 2·85; basalt 2·6; obsidian 1·6; Glauber Salt 15; mesotype 15·09; needlestone or mesolite 5·40; somnite 20·46; rubellite 10·; sodalite 23·5; lythrodes 8; analcime 10·; nephrite 10·75; saussurite 6·; cryolite 32; glauberite 51, sulphate; natron 75 carbonate of soda, 2·5 sulphate of soda, 22·5 water; pure carbonate 22· soda, 15 carbonic acid, 62 water. Natron occurs in the soil in some parts of Hungary, Bohemia and Switzerland, also in Egypt, Syria, China and the East-Indies. Hence by the water draining through the earth and carrying off the natron in solution, lakes are formed; and the water being evaporated in the dry season, thick beds of this substance are left, which being removed, it becomes an article of commerce. The eudyolite contains 13·822 of natron, the natrolite 16·50. the spinellane 19. Nitrate of soda occurs in beds of some feet in thickness, and of more than forty leagues in extent, near the southern extremity of Peru.

4. LITHIUM.

56·5 Lithium, 43·5 Oxygen---Lithia.

This is the metallic base of the newly discovered alkali, lithia. It is of a white colour and very similar to sodium; but so great is its attraction for oxygen, that the specimen obtained was soon, by being exposed to the atmospheric air, converted into lithia. It is a very rare substance, having only been found in a few very rare crystallized minerals. *Lithia* has an acrid, caustic taste, is very soluble in water, differs a little in some of its characters from the other two fixed alkalies, but not more than they differ from each other. It occurs in the following

MINERALS: lepidolite 3·502 per cent., petalite 5·7, spodumene 8·85, also in amblygonite and meionite, though in very small quantity in the latter.

5. CALCIUM.

72 Calcium, and 28 Oxygen—Lime.

CALCIUM is a very bright metal, as white as silver; burns, when a little heated, with an intensely white light, and is rapidly converted into lime. In this state it is always found in nature, but mostly combined with an acid, especially the carbonic; thus forming about an eighth part of the crust of the globe. It occurs in almost all plants and vegetable substances; and also in most of the animal substances, but especially in bones, shells, horns, hoofs, nails, claws and hair.

Lime, quick-lime, or calcareous earth, when pure, is white, hot and caustic to the taste, and changes vegetable blues to green. It will solidify one fourth of its weight of water, yet remain unchanged in its visible qualities. The water, passing into a solid state or becoming combined, parts with its caloric of fluidity, hence the principal part of the heat evolved in slaking quick-lime; and as the caloric must be evolved from the water while combining, therefore, lime has the peculiar property of dissolving more rapidly in cold water than in hot, but it dissolves only in about 400 times its weight in either. Its specific gravity is 2·3.

The chief affinity of lime seems to be for carbonic acid, which it rapidly absorbs from the atmosphere, and is converted into chalk or limestone. Bishop Watson, by experiment, found that a ton of quicklime newly drawn from the kiln, and exposed to the atmosphere, absorbed daily one hundred weight of carbonic acid for the first five days. On this account, quicklime is found to be a great promoter of dissolution in vegetable and animal substances, and is sometimes used to hasten the decomposition of dead bodies. On the same principle it is used in various arts, as tanning, purifying sugar, and in almost all cases where carbonic acid is to be separated. It is said that carbonate of lime has the property of preventing acidity in the alcoholic fermentation. In bleeching and some other processes, lime acts like the alkalies. For manure, see c. XVIII. and for building, see magnesia.

MINERALS. Lime enters into the composition of numbers of the earthy and crystallized minerals; but never, except when mineralized with an acid, above 50 per cent.; and its general proportion is from 9 to 25. It is found combined with the carbonic, phosphoric, fluoric, sulphuric, nitric, boracic, and arsenic acids.

Carbonate of lime varies from 44 to 56 lime, and from 56 to 44 carbonic acid; it forms about 30 mineral substances, among which are common limestone, marble, calcareous spar, verd antique, oolite, chalk and tufa. *Phosphate* 54·28 lime, 45·72 acid apatite, and phosphorite. *Fluate* 67·75 lime, 32·25 fluoric acid, fluor. *Sulphate*, gypsum. *Nitrate*, nitrate of lime. *Borate*, datholite 34 lime, botryolite 39·5. *Arseniate*, pharmacolite 25 lime, 50·54 arsenic acid, 24·46 water.

Precious stones. Precious garnet 3. Common garnet 20 lime. Lapis lazuli 28 carbonate. Chrysoberil 6. Cinnamon stone 31. Green tourmaline 4. See Mineralogy, sec. 14.

6. MAGNESIUM.

62 Magnesium, 28 Oxygen—Magnesia.

THIS substance is but imperfectly known; it has the same whiteness and lustre of some of the other metalloids; it sinks in water, and therefore must have considerable specific gravity. It has a greater affinity for oxygen than calcium, is soon covered with a crust of magnesia when exposed to the air, and if strongly heated, burns with a red light, and is converted into its earth. Magnesia is not an abundant ingredient in rocks, and is chiefly confined to serpentine, basalt, certain varieties of limestones, and occurs in about 30 crystallized minerals, or such as are found in veins. It abounds in the waters of the ocean, and in certain spas; it hence becomes an ingredient in most marine plants. The salsola soda contains no less than 17·927 per cent.

The earth in a pure state is sold by the druggists as calcined magnesia. It is a perfectly white, very soft and light powder, without taste or smell. It assists the fusion of many other bodies, and is much used with silica in the manufacture of porcelain, though by itself it is unalterable in the fire. It promotes the solution of camphor, opium, and resin in water; though will hardly dissolve by itself, and requires even 2,000 times its weight of water to hold it in solution; so that it

absorbs and solidifies a great deal of this fluid, expelling its caloric. Calcined magnesia has most important uses in medicine. It is the most effectual antidote in case of poison by the mineral acids; and an upheaped table spoonful in half a pint of water, given immediately after oxalic acid has been taken, will save life. It is also useful as an absorbent to correct acidity in the stomach; but if taken as an aperient, the carbonate or mild magnesia ought to be used. If a little calcined magnesia be agitated in putrid water, it will, in a few minutes, lose its bad taste and smell.

The affinity of both lime and magnesia for silica and carbonic acid and water is very great, though the latter does not absorb the water and acid so rapidly as the former; and, therefore, the mortar from the magnesian limestone makes a much better cement for building than that procured from the more pure carbonate of lime. Because lime alone has nearly formed its combinations before it is built, and therefore cannot knit well; but when the mortar contains magnesia, it more gradually obsorbs acid from the atmosphere, and solidifies the water with which it is made up; and this process will continue for centuries, so that in some old buildings the cement is found as hard as the strongest limestone.

Minerals. Magnesian fossils generally have an oily feel, a silky lustre, and fibrous texture. For fuller's earth, hornblende, phosphate, serpentine, feldspar, talc, green earth, soapstone, steatite, potstone, chlorite, basalt, dolomite, see sec. 14. Among the 39 minerals that are principally found in veins, are, the Tremole 25 per cent. Actynolite 20. Hypersthene 14. Schillar spar 29. Smaragdite 3. Amianthus 29. Oriental turquoise 2. Spinelle ruby 8·78. Lazulite 18. Chrysolite 50. Meteoric Olivine 38·5. Tourmaline 8·47. Hydrate of magnesia composing small veins in serpentine 69·75 mag. 30·25 water. Carbonate of magnesia, 48 mag. 49 car. acid and 3 water, occurs also in serpentine.

7. BARIUM.

90 Barium, 10 Oxygen—Barytes.

This metalloid has the appearance of a dark grey silvery metal, but with a lustre inferior to that of the fracture of cast iron. At the common atmospheric temperature it is solid, and

requires considerable force to flatten it, but becomes fluid at a heat below redness. It is soon tarnished by exposure to the air, and is converted into barytes. When thrown on water it immediately sinks, but produces a violent chemical action, being soon converted into its earth, and evolving hydrogen gas. It is but a rare substance, having only been found in metallic veins in two or three minerals. It is a deadly poison in all its compounds; though the muriate is much used in medicine, especially in scrophulous and chronic diseases.

Barytes, has very great specific gravity, being more than four times heavier than water; it is a greyish white powder, with a sharp caustic taste, changes red vegetable colours to violet or blue, and yellow to brown; makes oil miscible with water, and forms glass with silica; in short, it has all the alkaline properties and some others, and is therefore a most valuable chemical test. It swells when exposed to the air, also in slaking like quicklime, but not so rapidly; it likewise solidifies with water, forming a very tenacious cement. It composes the only white paint, that will keep its colour in water painting: when prepared for this purpose, it is sold by the name of "Hume's permanent white." Its chief affinity is for sulphuric acid, which it will detach from all other combinations, forming with it a compound insoluble in water; though the earth itself may be known from all others by its great solubility in water.

MINERALS. *Sulphate* of barytes or heavy spar, is the heaviest of all earthy minerals, having a specific gravity of about 4·7; and is composed of 67 barytes and 33 sulphuric acid. It occurs both massive and crystallized, with a lamellar structure. When massive it is sometimes curved, and its primary crystal is a right rhombic prism. It is met with transparent, white and opaque, yellowish or yellow, reddish, greenish grey, and bluish or blue:—its presence imparts a yellow colour to flame. It is found in the leadmines of Derbyshire, where it is called *cawk;* it also occurs at Alstone Moor, in Arkendale, and Cornwall. Several varieties are found on the continent, one of which, called Bolognian stone, is remarkably phosphorescent when heated. *Carbonate* or *Witherite*, consists of 78 barytes and 22 car. acid. Specific gravity 4·3. It occurs massive, stalactitic, and crystallized, It abounds in the lead mines in the north, and is found in several other mines. *Harmotome* 49 silica, 16 alumina, 18 barytes and 15 water occurs in Scotland and on the continent. Barytes occurs in an ore of manga-

these 14·7 per cent. In the chapter on geology, we shall have to mention casual minerals of this metalloid, which are occasionally found in the flœtz formations.

8. STRONTIUM.

86 Strontium, 14 Oxygen,—Strontites.

THIS metalloid resembles barium in some of its properties; it has little lustre, is not volatile, and is fusible with difficulty, but is not poisonous. It is but a rare substance, its minerals having never been found forming the mass of a rock.

The earth *strontites*, strontian, or strontia, is, like all the earths, when quite pure and well dried, perfectly white, and has sometimes been mistaken for barytes, which in many of its properties it resembles, but it has less of the alkaline taste. "It burns with a purple flame, but when mixed with alcohol, or any other moist combustible, the flame is carmine; and its specific gravity is only half that of barytes or 2.' It is soluble in 200 times its weight of cold water, but dissolves more readily in hot, and crystallises in cooling. Muriate of barytes crystallizes in rhomboidal plates, but muriate of strontites in slender hexagonal prisms.

MINERALS.—Strontianite or carbonate of strontian, 69·5 strontites, 30· carbonic acid, 0·5 water, was first discovered at Strontian in Scotland, in a vein passing between gneis and granite, with fragments of the latter interposed, and accompanied by galena, heavy spar, calcareous spar and iron pyrites. It is massive, fibrous, stellated and crystallized, its fragments are generally cunical. It is of a greyish or greenish colour, brownish, or deep brown. Barystrontianite, or stromnite, was found in masses on mica slate at Stromness, 68·6 sulphate of strontites, 27·5 sulphate of barytes, 2·6 carbonate of lime, 0·1 oxide of iron, 1·2 loss. The *arragonite* contains 3·9 per cent. of carbonate of strontites. But celestine seems to be its most abundant mineral. One specimen consisted of 73 sulphate of strontites, 26 166 sulphate of barytes, 0·213 alumina and oxide of iron. It seems to belong to the new red sandstone, or red marle formation; and is principally found on the detached parts of it where it makes the nearest approach to the primary districts. But it occurs on the banks of the Nidd near Knaresborough, Yorkshire. Near Bristol, also near Paris and in

Pensylvania, it is found in such quantities as to be used in repairing roads.

9. SILICIUM.

31 Silicium, 30 Oxygen,—Silica or Silex.

THOUGH this substance is classed among the metalloids; yet, on a second consideration, Sir H. Davy, did not think it of a metallic nature, but a peculiar substance bearing an analogy to boron, carbon, sulphur, and phosphorus. It enters largely into the composition of cast iron, for which metal it seems to have considerable affinity: hence, perhaps, it is that flint and steel by collision afford more brilliant sparks than can be obtained by any other means. The particle struck off is always found to consist of a globule of cast-iron, so that a chemical union must have taken place, the combination in all probability being facilitated by the carbon contained in the steel. Silicium, next to oxygen, is the most abundant substance in nature. Combined with oxygen as silica, it is calculated to form above one-half of the solid crust of the globe. It occurs, though sparingly, in the vegetable kingdom, forming the epidermis of the grasses, stalks of corn, reeds and canes; and has occasionally been detected in some animal productions, as hair, &c.

Silica, silex, sandstone, or flint, is found in the greatest purity in quartz or rock crystal, when these, or any silicious, or flint stones are heated red hot and thrown into water, they are rendered white, brittle, and capable of being pulverized, or reduced to silicious earth of greater or less purity, according to the composition of the stone. Its specific gravity is 2·26. It is perfectly white, void of taste or smell, neither soluble in water or any acid except the fluoric, and resists all heat except that of the hydrogen and oxygen blow-pipe. Yet nature seems to dissolve it in the formation of stalactitic minerals, or those crystallized earthy substances found in veins, and cavities, the basis of two-thirds of which is silica. The chalcedonic class of minerals are also supposed to have had a similar origin, but are sometimes petrified organic substances, as flints, agates, &c. The beams of timber, that supported Trajan's bridge across the Danube, were examined in the year 1760; and the outer parts of the timber to the depth of half an inch were found to be converted into agate; the more inward part

was slightly petrified, and the centre was still wood. So that the silicious matter displaces that of the wood, and solidifies in its place; hence such productions often exhibit the structure of the organic remains, as some agates display the cortical layers of wood. The hot fountain in Iceland contains silica in solution, which there precipitates and forms an incrustation around the crater, and silicious stalactites abound in lavas.

Silica is very easy of solution with the fixed alkalies, with which it forms glass. For transparent *crown* glass only silica and alkali is used; but they must be kept a long time exposed to a very intense heat, as they retain the last particles of water with very great obstinacy. The ingredients for the composition of *flint* glass, in London, are, 120 white sand, 40 pearl-ash, 35 red oxide of lead, 13 nitrate of potash, and 25 black oxide of manganese. Plate glass contains a little lime but no lead. For common green bottle glass, a portion of basalt has lately been used, or the waste alkaline ashes of the soap boilers supply the place of the pure alkali. It is an oxide of iron, contained in the basalt and in the common wood ashes, that are frequently introduced in the manufacture of this glass which gives it the colour. For that opaque kind of glassy substance, called *enamel*, 100 lead and 30 tin are calcined in a furnace; and then these oxides are fused with 100 silica and 20 potas. Additional metallic oxides give the different colours.

MINERALS.—Silica is the most abundant substance in nature. It has never been found mineralized by any acid, but it occasionally enters, in very small proportions, into some of the acidiferous earthy substances. Its minerals include the hardest gems and the softest clays; in short, it forms a full half of the most tenacious soils. It is found in the composition of a few rare and crystallized metalliferous minerals in the proportion of 30 or 40 per cent., and in small proportions in the most abundant ores of iron. For the composition of the massy rocks see sec. 14.

Quartz is pure silica. But under this general term are comprehended many minerals, which are considered as varieties, because they consist almost entirely of silica, with perhaps a very minute quantity of the oxides of iron which gives them a variety of colours, and a small portion of water, generally as the water of crystallization; but on the whole, the quantity of foreign ingredients is so small that it does not affect the form of the crystal; which is a six-sided prism, terminated by six-

sided pyramids; but sometimes, though rarely, the bases of the pyramids are joined without an intervening prism. The cross fracture is often perfectly conchoidal. In some of their external characters they widely differ, in others they mostly agree; they are sufficiently hard to scratch glass, and when compact will strike fire with steel; when two pieces of quartz are rubbed together in the dark a phosphorescent light is produced, and an odour like that of the electric fluid. They occur in the fissures, veins, or cavities in most of the rocks that contain silica in their composition, but they often include other substances: the following are the principal of them; rock-crystal, avanturine, prase, milk-quartz, rose-quartz (Bohemian ruby), violet or amethist, yellow or Bohemian and Scotch topaz often called Cairngorm, brown, ferruginous or hyacinth of Compostella, irisated, radiated, fat or fetid, having a greasy feel and giving out a fetid odour, hyalite, cat's-eye, opal with its varieties.

Chalcedony includes several varieties of minerals, agreeing in their general characters and differing only in colour. It is composed of about 84 silica and 16 alumina. It occurs, massive; forming veins; in nodules; in botryoidal masses; and stalactitical. It sometimes exhibits organic impressions, but is never crystallized. The *onyx* consists of alternate layers of brown and white chalcedony, and when cut exhibits opaque white circles resembling the iris of the eye. *Sard* is of a deep, rich, reddish brown colour, which, by transmitted light, approaches to blood red. *Sardonyx* consists of alternate layers of onyx and milk white chalcedony. *Plasma* is of a dullish green colour, with yellow and whitish dots supposed to be chlorite. *Heliotrope*, bloodstone, and finest varieties, Oriental jasper, has a deep green colour with blood red spots. *Chrysoprase* contains a little magnesia, oxide of iron, and nickel, and is of an apple green colour. *Carnelian*, is composed of 94 silica, 3·5 alumina, 0·75 iron. Chalcedony, also, forms the basis of *agate*, of which there are five or six varieties; but they sometimes consist of other precious gems coated by chalcedony.

Jasper comprehends a variety of minerals, distinguishable from the agate by their opacity. The most common colours are yellow, brown, and red, of various shades, and sometimes green, occasionally intermixed with spots and irregular veins. The Egyptian consists of 75 silica, 15 alumina, and 5 magnesia. It is found along with masses of petrified wood, among which

is the palm, scattered over the sandy desert between the borders of the Red Sea and Grand Cairo.

The *Garnet*, includes about a dozen varieties that differ considerably in their composition; the *precious* consists of 35·75 silica, 27·25 alumina, 36 oxide of iron, 0·25 oxide of manganese. Its colour is a beautiful red of various shades, having, sometimes a tinge of yellow or blue, or a smoky aspect. It belongs to primary rocks, and is chiefly found in mica slate. The *common* garnet is very abundant in all the older rocks.

Lapis-Lazuli, from which is made that beautiful pigment called *Ultra-marine*, consists of 64 silex., 14 alumina, 28 carbonate of lime, 6·5 sulphate of lime, 3 oxide of iron, and 2 water. It is of a fine azure blue colour, and occurs in small masses in primary rocks, principally granites; the finest specimens are brought from China, Persia, and Great Bucharia.

10. ALUMIUM.

54 Alumium, 46 Oxygen,—Alumina.

The basis of alumina is of a white colour, and appearances were in favour of its being of a metallic nature, but it has not yet been obtained in such a state as to render a minute examination of its properties practicable. It seems of an alkaline nature, but by reason of these properties being so strong and its affinity for oxygen so great, its true nature has not yet been ascertained. Combined with oxygen as alumina, it is next to silica the most abundant substance in nature, forming one-third or one-fourth of all argillaceous substances, and has been detected in very minute quantities in the vegetable kingdom.

Alumina, alumine, argil, or pure clay, is perfectly white, soft to the touch, adhesive to the tongue and destitute of both taste and smell; but one of its characters when in composition, and by which its presence may always be known, is, that when the mineral is breathed on, it gives out a peculiar smell termed the argillaceous odour. However, as it does not belong to pure alumina, it is supposed to be owing to the presence of the oxide of iron, which is generally a component ingredient of argillaceous minerals. Alumine is nearest to a state of purity in the corundum and its varieties; but is never found quite pure or in a native state except perhaps at Halle, in Germany: its specific gravity is 2. It is soluble in all the acids, as well as in the

fixed alkalies; shrinks in the fire at very high temperatures, and may be fused with the blow-pipe, when it forms a vitreous substance sufficiently hard to scratch glass. Being impervious to water, it is of great service in securing the bottoms and sides of canals; and it forms a paste with water that may be moulded or fashioned into any shape. Owing to the alkaline properties of the alumina, fuller's earth is useful in scouring woollen cloth. With the oxides of iron it forms ochres, and in this state it abounds in Staffordshire and Derbyshire, where it is known by the name of *raddle*, a substance much used in colour making.

Alumina has a great affinity for colouring matter, so that it is an important article in the hands of the calico printers, but chiefly as *alum*, a peculiar salt of which this earth forms the basis, and from which it takes its name. Alum is a triple salt, being a sulphate of alumina and potas. Sulphate of alumina, or alum shale, abounds in the Lias formation, especially on the Yorkshire coast; and a part of the alkali is procured from burning this shale with brushwood, &c. the other is supplied from the potas of commerce. A manufactory was established near Guisbrough, in defiance of the Pope, in the time of Queen Elizabeth; and has with little intermission continued somewhere along the coast, especially near Whitby, ever since. There is now one carried on near Glasgow; abundance of aluminous schist having heen laid bare and formed by the workings of a coal mine. At this place ammonia, procured from putrid urine, is used instead of potash. The most ancient manufactory known of was at Roche in Syria, hence the term Roch-alum. It has a variety of uses in the arts, but most of them seem to depend upon the properties of the alumina.

Alumina is what gives the plastic character to those clays or earthy substances of which bricks, tiles, earthenware, china, and porcelain are made: though in all these, silica forms the better half, and alumina only about one-third of the whole, the rest is chiefly oxide of iron, with lime or magnesia in small proportions. But indeed some of the most esteemed porcelain earths, when analyzed, proved only silica and magnesia. For the formation of *tiles*, *bricks*, and the *coarsest earthenware*, the clay is generally used as it is taken out of the pits, full of impurities. When there is a superabundance of silica, the articles want tenacity and are brittle; and when there is too much alumina they shrink and crack in baking; the oxide of iron gives

them their red colour, and where lime or magnesia is in knots or in quantity above a certain proportion, it swells from the attraction of moisture and carbonic acid from the atmosphere, and causes the whole to crumble in pieces; should they not be sufficiently fired, the ingredients are not chemically combined in the mass and they attract moisture, when the articles become shivery.

For the *finer earthenware* the clay is purified and mixed with a certain quantity of burnt and ground flint; but for *stone ware*, finely ground old pottery is used, and it is baked with a greater degree of heat and differently glazed. Stone ware, as well as the *brown* and some of the *white*, have but one firing: for while they are in the oven, the fumes of muriate of soda are let in among them, which is decomposed by the heat, the chlorine or muriatic acid is dispersed, and the soda forms a chemical union with the silica of the clay, and thus vitrifies the surfaces of the articles. The others are glazed with the oxide of lead, which is pernicious, and even paralizes the hands of the workmen when much employed. Stone ware, therefore, not only on account of its compact texture and durability, but also of the wholesome nature of its glaze, is to be preferred. The *fine white* or *cream coloured*, after being molded on the wheel, is baked, then dipt in a vitrified liquid, principally lead, and is baked a second time for the glazing. If painting and enamel are required, they have a third baking.

Porcelain or *china* generally contains a little magnesia, which tends to prevent its shrinking by fire. Beds of porcelain clay generally occur in granitic rocks, and often include crystals of feldspar, of quartz and of mica: one specimen consisted of 52 silica, 37 alumina, and 6·33 oxide of iron. It is supposed to arise from the decomposition of feldspar. The chief characteristics of porcelain, are, compactness of texture, purity of white, and semitransparency; this last principally distinguishes it from earthenware which is always opaque. The beautiful colours of its paintings are made with metallic oxides. Purple is obtained from gold, yellow from silver, green from copper, blue from cobalt, violet from manganese, and red from iron. The figures are done, by being stamped on paper, and applied while the ink is wet, but they are farther touched up by the hand or pencil. The Chinese alone, till the beginning of the 18th century, seem to have possessed the art of making porcelain. It was so scarce and so valued among the ancients,

that at the sacking of Alexandria by the Romans, the Emperor Augustus retained as his part of the spoil, only a porcelain vessel, which in all probability had come from China. The porcelain tower of Nan-king in China is among "the wonders of the world." It is an octagonal building of nine stories; each story decreasing in width as the superstructure rises to the height of 300 feet. All this tower is covered over with the most beautiful china, and has stood for more than 400 years, exposed to the sun and all kinds of weather with undiminished splendor.

MINERALS.—Alumina is an ingredient in a large proportion of some of the most abundant rocks, primitive, secondary and alluvial; and is found in all soils; also in small proportions in a few ores, especially certain of the ores of iron; but it does not compose above one-third of any of the argillaceous minerals, except a few of the precious stones, among which are the following.

The *corundum* includes: the perfect corundum, common corundum and emery. Under the first are included the sapphire and oriental ruby, which, next to diamond, are the most valuable of the precious stones. The *sapphire* is composed of 98·5 alumine, 0·1 lime, and 1 oxide of iron, another analysis gave no lime, but 5·25 silica. The sapphire has many names depending on its colour and lustre, among which are the oriental amethyst, violet and blue; the oriental topaz, yellow; oriental emerald, green. The *oriental ruby* is of a blood red colour, but is occasionally rose red, or has a tinge of violet, it consists of 90 alumina, 7 silex, and 1·2 oxide of iron. The sapphire and ruby differ principally in colour and hardness—the latter being the less hard. Their specific gravity is about 4. The primary crystal a slightly acute rhomboid; the ruby is chiefly in six sided prisms. They occur in the vicinity of primitive mountains, and some of the trap-rocks. The finest are brought from Ceylon, but they have been found on Mont St. Gothard, in Bohemia, France and Portugal. The common corundum sometimes called *adamantine spar* from its hardness, occurs in granite chiefly in the mountains of south-eastern Asia, viz. China, Ava, Malabar, the Carnatic, Bengal, and Thibet, but has also been met with in Piedmont and Sweden. It consists of 86·5 al., 7 silica and 4 oxide of iron. Emery is composed of 86·5 alumina, 8 silex and 4 oxide of iron.

The *topaz* is sometimes limpid and nearly transparent, or of various shades of yellow, green, blue, lilac, or of red, and

translucent. It is mostly electric by heat with polarity, and has a specific gravity of 3·5. The white Brazilian topaz consists of 50 alu., 29 silica, and 19 fluoric acid. But the quantity of this acid varies from 4 to 19 per cent., and the yellow contains a small portion of the oxide of iron. It belongs almost exclusively to primary districts of the oldest formation, and chiefly occurs in tin veins traversing granite.

Crysoberyl, sometimes called the oriental, or opalescent chrysolite, is of a green colour, sometimes with a yellow or brownish tinge, and occasionally shews a bluish white light internally. That of Brazil is composed of 71·5 alumina, 18 silica, 6 lime, and 1·5 oxide of iron. It is chiefly found in Brazil along with topazes, but occurs along with sapphire in the sands of the rivers of Ceylon. In North America it occurs in granite with garnet and emerald.

The *spinelle* ruby consists of 84·47 alumina, 8·78 magnesia, and 6·18 chromic acid. It is of various shades of red, violet, or yellow, sometimes black, which are supposed to be produced by different proportions of the acid. It has various names according to its colour, and chiefly occurs along with the perfect corundum. About 13 other minerals, wherein alumina forms above 50 per cent., might be enumerated.

11. ZIRCONIUM.

The earth, zircon, or zirconia has not been completely decomposed, but the existence of oxygen has been proved by placing potassium in contact with it when ignited in the galvanic apparatus; by which means the oxygen of the zircon united with the potassium, forming potas blended with dark metallic particles. The quantity of oxygen, or the nature of the base is therefore not known. It is sparingly found, and has not been put to any use.

Zirconia has a specific gravity of 4. It is a fine white powder, without taste or smell, rough to the touch, insoluble in water, or the pure alkalies, but may be solved in the acids, though not after it has been heated to whiteness. If kneaded with water and cooled gradually, it assumes the semitransparency of horn.

Minerals.—The minerals, which are principally composed of zircon, are, the *hyacinth*, the *jargoon*, and the *zirconite*, crystallized. The hyacinth consists of 70 zir., 25 silica, and 0·5 oxide

2 P

of iron, with some alumina. It is of various shades of red, passing into orange red, and is transparent or translucent, and of a lamellar structure. It is considered of volcanic origin, and is found in France, Italy, Bohemia, Ceylon and Brazil. The jargoon occurs in Ceylon, also in France; it is of a greyish, yellowish, brownish, or reddish colour, and is composed of 66 zir., 31 silica, and 2 oxide of iron. The composition of the *zirconite*, is, 64 zir., 34 silica, 0·25 oxide of iron, and 1 titanium. It is of a reddish brown colour and nearly opaque, and occurs in granite, gneis and sienite. The exposure of some of this class of minerals to heat deprives them of their colour, and it is said that they have been, in this case, sold as diamonds. The eudyalite, a mineral found in Greenland, contains 11 per cent. of zircon.

12. GLUCINUM.

70 Glucinum, 30 Oxygen,—Glucine.

Sir H. Davy, in his experiments on the earth, glucine, or glucina, found such appearances as warranted him to conclude that it consists of oxygen united to a highly inflammable metallic base. The earth is a white, soft, light powder, destitute of taste or smell, somewhat unctuous to the touch, and adhesive to the tongue, is infusible by heat, insoluble in water, but yields to the acids, and with them forms sweet tasted but slightly astringent salts. Like alumina, it is soluble in the pure liquid alkalies, though not in ammonia, unless it is the carbonate. It is a very rare substance occurring only in the following

Minerals: viz., the euclase, beryl, emerald, gadolinite and topazolite. The *euclase* consists of 21·78 glucine, 43·32 silica, 30·56 alumina, 2·22 oxide of iron, 0·70 oxide of tin. It is either colourless or nearly transparent, or light green of various shades, or bluish green and blue, and has a specific gravity of 3·06. It is found in Peru and Brazil. *Beryl* or aqua-marine, is of various shades of pale yellow, green, and blue. Its crystals have been met with more than a foot in length, and four inches diameter, and nearly transparent. It is composed of 14 glu., 68 silica, 15 alumine, 2 lime, 1 oxide of iron. It is considered as a variety of the emerald, and occurs in most primary mountains. The *emerald* consists of 13 glucine, 64·5 silica,

16 alumina, 1·6 lime, and 3·25 oxide of chrome. Its colour is a pure and beautiful green of various intensity. It never occurs in very large crystals, and belongs to primary mountains; the finest are found in Peru, but those of the ancients came from Upper Egypt. Those large ones, spoken of by various writers, are supposed to be green fluor or prase. Gadolinite contains about 5·5 per cent., and topazolite 4.

13. ITTRIUM.

THE only reason there is for classing the base of the earth Ittria or Yttria among the metallic substances, is, that in experiments similar to those by which zircon was examined, it gave out oxygen; hence it is supposed to be like the other earths: viz. oxygen united to a metallic base. The earth is much like glucine, being a fine white insipid powder, forming sweetish salts, but its peculiar, and distinctive feature, is, its great specific gravity, which is 4·842—being greater than that of any other earth. It is insoluble in water and the caustic alkalies, but easily dissolves in a solution of the carbonate of ammonia. It also readily dissolves when mixed with borax, in which combination it forms a white glass. It is a very rare substance.

MINERALS.—The gadolinite found at Ytterby near Roslagen in Sweden, is composed of 45·93 ittria, 16·90 protoxide of cerium, 24·16 silica, 11·34 green oxide of iron, 0·60 water. It is a dark iron-black ore, crystallized in oblique rhombic prisms, which have a resinous and sometimes a metallic lustre. It is inbedded in flesh-red feldspar and gneis. But its composition varies, sometimes it contains glucine as above stated, also manganese and alumina: a variety contains thorina. The other minerals in which it occurs are the orthite 3·44 per cent.; Yttrocerite 14·60; Yttrocolumbite combined with oxide of iron 55· and 45 oxide of columbium. It is found, also, in the neutral fluate of cerium.

14. MINERALOGY.

MINERALOGY is opposed to geology as treating of the internal structure of unorganized matter, or the arrangement which the original particles have made among themselves, so as to form crystals or consolidated into rocks:—it therefore has che-

mical affinity or the attraction of cohesion for its basis: while geology treats of unorganized matter in separate masses, and the arrangement of these masses in the formation of the earth's crust; it consequently has its foundation in the great revolutions which have taken place in the earth's surface since the creation. The one therefore contents itself with the investigation of a crystal, or a very small fragment of a rock; and leads the mind to contemplate the hidden processes that have been carried on, and are still going on, within the silent and peaceful bosom of the earth: the other attempts to explore the excavation of a valley, the immeasurable bulk of a lofty mountain, or the hidden stores of the mine; and presents the imagination with a contrast between the almost imperceptible changes now taking place on the earth's surface, and the wild confusion that prevailed, when the mighty mass of waters of the ocean retired from our present continents, or our primitive mountains received their birth amidst the contention of these waters with the vast volumes of fire which broke forth from the earth's solidifying mass. But as they both have for their object the investigation of the earth's shell, so they have a right to be considered as different branches of the same science.

It will perhaps assist the reader in forming a general idea of the composition of the earth's surface, or so much of the whole mass of our planet as is known to man, if we here arrange under one view and without any comment the composition of the various rocks, as near as we can, in the same order in which they occur in nature; beginning with the oldest or lowest of the rocky masses; and then add a few remarks on such of them as are not described elsewhere. The following rocks, then, compose the earth's surface; and are partly heaped one upon another, and partly laid side by side, nearly as they have been formed. The minerals, we have described in the preceeding sections of this chapter, are, either masses of no great extent, or crystalline substances that have chiefly been formed by the stalactitic process, in the crevices, clefts, veins, or cavities; and nearly all the metals of the following chapter, with the exception of iron, are found in veins; that is, under such circumstances, as lead us to conclude, that these massy rocks were split by a power operating beneath, and that the metallic matter was ejected or sublimed from a much lower depth into the cleft.

Quartz-rock, 98 silex, water, and varying proportions of oxide of iron.
Feldspar, (common) 62·83 silex, 17·02 alumine, 3 lime, 13 potash.
- - (compact) 68· silex, 19 alumine, 1 lime, 5·5 potas, 5·5 iron, 2·5 water.
Mica, 46·10 silex, 31·16 alumine, 8·39 potas, 1·12 fluoric acid, 8·65 oxide of iron, 1·40 oxide of manganese, 0·87 water.
Talc, 61 silex, 30·5 magnesia, 2·75 potas, 2·5 iron, 0·5 water.
Hornblende, 42· silex, 12 alumine, 11 lime, 2·25 magnesia, 30 oxide of iron, 0·25 ferruginous manganese.
Hornblende, (deep green) 47·21 silex, 13·94 alumine, 12·73 lime, 21·86 magne., 2·28 green oxide of iron, 0·57 olive oxide of manganese, 0·90 fluoric acid, 0·44 water.
Statuary marble, 56 lime, 44 carbonic acid, occasionally a little silex.
Serpentine, (common) 44 silex, 44 magnesia, 2 alumine, 7·3 oxide of iron, 1·5 oxide of manganese, 2 oxide of chrome.
Serpentine (noble) 42·50 silex, 38·63 magnesia, 1 alumina, 0·25 lime, 1·50 oxide of iron, 0·62 oxide of manganese, 0.25 oxide of chrome, 15·20 water, 0·05 loss.
Dolomite 59 carbonate of lime, 40 carbonate of magnesia.
Augite 48 silex, 5 alumine, 24 lime, 8·75 magnesia, 12 oxide of iron, 1 manganese.
Flinty-slate (Lydian stone or touchstone a variety) 75 silox, the rest lime, magnesia, and oxide of iron.
Clay-slate 48 silex, 25·5 alumine, 1·6 magnesia, 11·3 oxide of iron, 0·5 oxide of manganese, 4·7 potas, 0·3 carbon, 7·6 water.
Soapstone 45 silex, 9·25 alumine, 24·75 magnesia. 0·75 potas, 1 oxide of iron, 18· water.
Steatite 64 silex, 22 magnesia, 3 oxide of iron, 5 water.
Potstone 38 silex, 7 alumine, 35 magnesia, 15 iron, with small portions of lime and fluoric acid.
Black chalk 64 silex, 11 alumine, 11 carbon, and a little iron and water.

The above, with some others, and several varieties and compounds, are to be found among the primary rocks; the transition rocks are chiefly combinations, but sometimes varieties of them.

Basalt of Staffa 48 silex, 16 alumine, 9 lime, 16 iron, 4 soda, 5 water, 1 muriatic acid.
Basalt of Saxony 44·5 silex, 16.75 alumine, 9·5 lime, 2·25 magnesia, 2·6 soda, 20 oxide of iron, 0·12 oxide of manganese, 2 water.
Basalt tufa of Calton Hill 50 silex, 18·5 alumina, 3 lime, 16·75 iron, 4 soda, 1 muriatic acid.
Greenstone of Salisbury Cragg 46 silex, 19 alumina, 8 lime, 17 iron, 3·5 soda, 4 water, 1 muriatic acid.
Clinkstone of Auvergne 58 silex, 24·5 alumine, 3·5 lime, 4.5 iron, 6 soda, 2 water
Chlorite 26 silex, 18·5 alumine, 8 magnesia, 43 oxide of iron, 2 muriate of soda or potas.
Obsidian 78 silex, 10 alumine, 1 lime, 6 potash, 1·6 soda, 1 oxide of iron.

Pitchstone 73 silex, 14·5 alumine, 1 lime, 1·75 soda, 1 ox. of iron, 1 oxide of manganese, 8·5 water, sometimes bitumen.
Lava 51 silex, 19 alumine, 10 lime, 4 soda, 14 iron, 1 water.
Pumice 77·5 silex, 17·5 alumine, 1·75 oxide of iron, 3 soda and potas.
Jade 53·75 silex, 1·5 alumine, 12·75 lime, 8·5 potas, 10·75 soda, 5 oxide of iron, 2 oxide of manganese, 2·25 water.
Asbestus (amianthus) 59 silex, 3 alumine, 9 lime, 29 magnesia.
Green earth 53 silex, 2 magnesia, 10 potas, 28 oxide of iron, 6 water.
Basaltic hornblende 47 silex, 26 alumine, 8 lime, 2 magnesia, 15 iron.

Most of the above, with some others, belong to the trap family, the rest are volcanic products.

The secondary marbles are a numerous class, principally carbonate of lime, or the same as common limestone 44 lime, 56 carbonic acid.
Bituminous limestone 49·65 lime, 40.1 carbonic acid, 8.8 alumine, 0·6 silex, 0·6 bitumen, 0·25 water.
Calp (of the Lias) 68 carbonate of lime, 18 silica, 7·5 alumine, 2 oxide of iron, 3 carbon and bitumen, 5 water.
Chalk 56·5 lime, 43· carbonic acid, 5 water
Phosphate of lime 54·28 lime, 45·72 phosphoric acid.
Sulphate of lime (gypsum) 32·7 lime, 46·3 sulphuric acid, 21 water.
Magnesian limestone 30 lime, 21 magnesia, 37 carbonic acid, 1 clay and oxide of iron.

These are all limestones, but there are several other varieties.

Lemnian earth 66 silex, 14·50 alumine, 6 oxide of iron, 8·50 water, 3·5 natron, with minute portions of lime and magnesia.
Cimolite 63 silex, 23 alumine, 1·25 oxide of iron, 12 water.
Slate clay 86 alumine, 4 silex, 10 carbon.
Potter's clay 51 silex, 25 alumine, 3 lime, with trace of manganese and water.
Iron clay of the Giant's Causeway 31 silex, 22 alumine, 4·5 lime, 25 oxide of iron, 15 water.
Gun-flint 98 silex, 0·5 lime, 0·25 alumine, 0·25 oxide of iron, 1 water.

The first three, viz. quartz, feldspar and mica, are the constituents of granite, and contain nearly all the ingredients found in the earth's crust, and nearly in the same proportion; hence, granite may be considered as the parent of all the rest. Thus all the sandstones, as the old red sandstone, the milstone grit, the sandstone of the coal measures, the new red sandstone, the sands of the oolites, the iron sand and green sand, may be considered as derived from the *quartz-rock*.

Feldspar, next to quartz is the most abundant material of the earth's shell, in short it constitutes from 70 to 80 per-cent of most granites. There are several varieties of it, constituted of varying proportions of the same elementary substances. It is the principal constituent of the trap family, and as it contains a considerable proportion of potas, that has a great affinity for water, hence the supposed origin of all argillaceous rocks and soils—Feldspar occurs of various colours, though the flesh red seems the most prevalent, the other colours are the blue, the grey, the green and milkwhite; it is found massive, crystallized and of a lamellar structure; it is sometimes irridescent and generally polishes with a pearly lustre.

Mica occurs disseminated in rocks, massive and in crystals, mostly consisting of thin plates that may be separated with a knife. It is of various shades of white, yellow, green, brown, and sometimes black. It is a constituent of granite and occurs in almost all the formations, especially the sandstones of the independent coal formation, and also in alluvial deposits. In some parts of Russia it is in plates of more than a yard diameter, is called Muscovy glass, and is used instead of glass in Russian ships of war. In Pensylvania it serves instead of window glass. In England it is useful for inclosing objects for the solar microscope, also in Sir H. Davy's safety lamp.

Talc is often mistaken for mica, but may be distinguished from it, by being only flexible while mica is both flexible and elastic. It occurs in hexagonal, tabular crystals; also massive and indurated. Massive of a greenish grey colour occurs in Cornwall.

Dolomite greatly resembles primitive limestone, but is much softer, it consists of fine crystalline grains, lamellar; is sometimes slaty; the mass is generally white with a tinge of yellow or grey. It mostly occurs in veins; one 40 feet wide is found betweens vertical walls of basaltic hornblende in Iona, a Scottish isle.

Augite is mostly met with in basalt and volcanic products in detached grains, small crystals or amorphous, and it is a matter of dispute, whether they had been left unfused by the volcanic action or crystallized among the lava. Its colour is green, brown, or brownish black, sometimes black, with or without lustre and opaque. It often occurs in the veins along with a variety of other crystalline substances.

Soapstone, is massive, nearly white, or grey, sometimes with a tinge of yellow and mottled with green or purple. It sometimes includes veins of *asbestus* into which it occasionally appears to pass. Amianthus or flexible asbestus occurs in very long and extremely slender fibres, which are very flexible and elastic, and of a whitish, greenish, or reddish colour. It is somewhat unctuous to the touch, has a shining or silky lustre, and is slightly translucent. Both soapstone and asbestus usually occur in veins of serpentine.

Steatite, of which soapstone is supposed to be a variety, occurs in primary mountains, especially serpentine, but in considerable masses, beds or veins. That of Cornwall, the Isle of Anglesey, and Skye, as well as the soapstone, is much used in the manufacture of porcelain. The Arabs are said to use it instead of soap. Humboldt says that the Otomaques, a savage race inhabiting the banks of the Oronoko, are almost supported during three months of the year, by eating a species of steatite, which they first slightly bake and then moisten with water. The New Caledonians are said also to eat it.

Lemnian earth is of a yellowish grey and white colour, frequently with ochreous spots on the surface. It was dug once a year in the isle of Lemnos with much ceremony; and when impressed with the Grand Seignior's seal it was called *Terra sigillata,* and formerly used in medicine.

Cimolite abounds in the island of Argenteria, formerly called Cimola. It was much used by the ancients as fuller's earth.

All the formations of rocks from the oldest to the newest, without one exception, contain crystalline substances that seem to have been formed subsequently to the arrangement of the strata. They exhibit no marks of having suffered by attrition, they are formed wherever they found a cavity, and are nearly related in composition to the rocks in which they occur. Now all the rocks, except trap and granite, are in strata, and it is agreed on all hands that their materials had been deposited from water. But the granite, serpentine, sienite and trap family, have been fused by heat; and though some of them have been deposited in the presence of water, yet their materials have not been suspended by the water, and so deposited from it. However both these and the older stratified rocks occasionally exhibit internally a crystalline structure. And all the rocks, but especially the oldest, are traversed by fissures more or less vertical. The

fissures in the oldest rocks contain the metallic ores; they are called veins, and in these the ores are generally in crystals, but along with the ores is always a variety of other substances mostly crystalline, which occupy the chief part of the vein, and very often the whole of it.

Now the circumstances under which crystals may have been formed are the following: *first*, when a substance was fused by heat, and then was cooled in a dry state, as granite, serpentine, sienite, some of the traps and the metallic ores. *Secondly*, when fused and deposited in the presence of water, as gneis and those traps which contain soda. *Thirdly*, as deposited from water, and afterwards partially fused by heat and electricity, so that the chemical affinities became active, and new combinations ensued, as in mica-slate, down to the new red sandstone; or *fourthly*, by the electricity only assisting the inherent fluids, so that a mere consolidation took place, and new combinations were on a less scale, as in the oolites, chalk, &c. *Fifthly*, the formation of stalactites, which was occasioned by the percolation of water carrying off the new combinations, and precipitating them in cavities, which equally took place in all the rocks, but mostly in the oldest, and gave rise to more than half the minerals enumerated in treatises upon this subject. And *lastly*, perhaps, sublimation from internal heat, which might deposit many of the metallic ores and some of the sparry incrustations.

15. CRYSTALLIZATION.

The characters of crystals are of two kinds, chemical and external; but though the extremes of each class are very widely apart; yet, so intimately are they connected, that we cannot say where the one terminates and the other begins. The chemical, in general, are such as arise from the simple elementary substances that enter into their composition, their definite proportions, and their combinations. Now as most minerals are variously compounded, one of the elementary substances may be present under a variety of forms; that is, it may have parted with one definite proportion of its electric fluid in one combination, with two in another, and with three or more in a third. Consequently, when the molecules of these different combinations come together, they will present different affinities; and if they are suspended in a menstruum that permits of a free

motion, or facilitates their movements, so that they may be intirely obedient to their inherent mutual attractions, the opposite sides or poles of each molecule, will dispose themselves according to their affinities.

For instance, calcareous spar or crystallized carbonate of lime, is composed of lime and carbonic acid; the constituents of lime are calcium and oxygen, and of carbonic acid carbon and oxygen. Now as carbon and calcium are never found combined without the intervention of oxygen, we suppose the attraction between these substances to be occasioned by the oxygen. But as the oxygen, in all probability, has parted with different proportions of its electric fluid, the attraction will only be in one of them; that is, if the oxygen combined with the carbon, has parted with one definite proportion of its inherent electric fluid, and that combined with the calcium, two; then, the calcium of the lime will attract the oxygen of the carbonic acid. Now suppose a molecule of lime to consist of an original particle of calcium and one of oxygen; and a molecule of acid to consist, in like manner, of an original particle of carbon and one of oxygen. As the positive electricity is predominant in the carbon and calcium, and oxygen is the storehouse of the negative fluid, each molecule will have a positive and negative pole. But as substances in which the same electric fluid is inherent repel each other, and those in which the opposite fluids are inherent attract each other; consequently, the negative or oxygen pole of the acid molecule will attract and combine with the positive or calcium pole of the lime molecule.

We have arrived at the above conclusion on the supposition of the calcium and carbon being elements, but we have already shewn, in Chap. IX. s. 6, that they must be compound substances; and, therefore, what we have considered as original particles must in fact be molecules possessed of polarities. This is an obstacle to our arriving at any idea of the figure or exact position of these original particles in the arrangement of our molecule of carbonate of lime, only we must conclude that it will possess a certain definite figure with polarities; yet, however this may be, when a second molecule joins with the first, it must join according to these polarities, as also a third; and, therefore, when a number of these are floating in a menstruum, as in water, or even in a state of sublimation, they will attract each other and solidify, but they must join according to their polarities. Now these original combinations are, perhaps,

millions of times too small to be detected by the sight; yet, we always find them as well as other like combinations, when such a number has been combined as we can see, possessed of more or less of a symmetrical or geometrical shape, being solids bounded by plane surfaces that meet at different angles. Yet the same combinations always present the same figure with the same angles; the smallest perfect crystal of carbonate of lime that can be observed, is, an oblate rhomboid; and its opposite angles are 105 deg. 5 min. and 74 deg. 55 min.

Though we are not yet able to pursue crystallization from the first combination of a few original particles, or molecules, to its full developement in the perfect crystal, for to do so is what Sir H. Davy supposes will "constitute the mature age of chemistry," to which age this science is far from having attained; yet, the above remarks will serve to point out to the reader the road on which its future cultivators must travel; and also the field wherein a great part of succeeding discoveries must be made. For to this source must be traced, all, or most of the external characters of minerals; such as are comprehended in the following list: external form, structure, fracture, frangibility, hardness, transparency, lustre, colour, flexibility, elasticity, double refraction, touch, taste, odour, streak, powder, adhesion to the tongue, magnetism, electricity, phosphorescence, and specific gravity.

It would far exceed our limits to offer remarks on all these characters, some of which belong to every mineral substance, others only to a few. Yet, from what we have already said, the reader may perhaps be able to form conjectures himself concerning some of them. *External form*, for instance: he will always find the most simple minerals, that is, such as contain the fewest elements in their composition, to present the most simple external forms; and vice versâ, those that are the most variously compounded have crystals of the greatest complexity of figure. This is a natural result of the original molecules of the most compound substances possessing the greatest number of poles, or the most complex polarity.

Structure. As each crystal is composed of an almost infinite number of molecules, and as these in joining together always preserve the same symmetrical form according to their polarities; so the external structure will display an almost infinite number of joints. For when the original molecules join, they will join with the poles that have the greatest attraction for each

other; consequently, the external parts or poles of these new molecules will have less attraction for each other than the internal. They will therefore cohere with less force than the internal; and consequently a crystal will sooner separate between these external than internal; and by reason of the symmetrical form preserved by the polarites, this will, in many cases, give rise to a lamellar structure. Each crystal must therefore possess a number of joints according to its shape, consequently we find that a crystal can only be cut or divided according to its joints, called its *cleavage*. Calcareous spar, for instance, can only be divided into rhomboids with the above angles; but as a rhomboid has six planes, which are parallel two and two, it therefore possesses natural joints in *three* directions. Other minerals will yield in many directions, though some only easily in one. But their cleavage has always a reference to the primitive crystal, that is, the smallest perfect crystal that can be obtained. The whole number of primitive crystals, as found in different minerals, are supposed to be comprehended under the following varieties; viz. the regular tetrahedron, the cube, the rhombic dodecahedron, the octohedron, the six-sided prism, and the parallelopiped. Now the crystals of a mineral from whatever part of the world, and however at first sight unlike each other in external form, will always possess such a mutual relation as will enable the observer to trace them to the same primary form.

Fracture. In cleaving a crystal, it is divided according to its joints, or, the external poles of its original molecules are separated, which having a less attraction for each other, is easily done, and the divided parts always display smooth surfaces or perfect planes. But *fracture* is here used to signify a division across or contrary to these natural joints, when perhaps some of the internal parts are separated. It, therefore, requires a much greater force to produce this kind of division than the other; and the fractured part always displays a rough and uneven surface.

Frangibility refers, principally, to the ease with which a substance may be broken to pieces; and its two extremes may be considered as very brittle and very tough. Perhaps it may be thus explained: when the compound molecules possess decisive polarities, the substance will be brittle; when they do not, it will be tough. Ice, or crystallized water, for instance, is composed of oxygen and hydrogen. Now those are both elements

a molecule of water, therefore, will present a decisively negative and positive pole. In the arrangement of the crystal, the same electric poles will be at the greatest possible distance: when these, therefore, are brought nearer to each other, by bending or hammering the ice, they become repulsive and fly asunder. But where more original particles are conjoined to form one original molecule, the polarities cannot be decisive, that is, a positive or negative original particle may always be interposed between two negative or two positive particles; consequently, two and two of a sort may not be opposed to each other, and therefore this repulsion will not take place. However, decisive toughness is not a character of crystals: for to be really tough an original molecule must be separated from its place, and yet retain its adhesion, when it is evident its crystalline structure must be destroyed. Now pure iron is supposed to have a crystalline structure and yet is tough. But by hammering, the original molecules (for all the metals are supposed to be compound substances) are brought nearer to each other, and it then becomes brittle. This may be said to be occasioned by the loss of caloric, since by smart hammering all the latent caloric is supposed to be beaten out; however, such is the intimacy between latent caloric, and the inherent or essential electric fluids in all substances, that we cannot in the present state of the science draw any line of distinction between them.

From what has been said of frangibility, it is easy to account for hardness, flexibility, elasticity, and specific gravity.

Hardness must depend upon the force with which particles attract each other; and differs from toughness, in their unwillingness to approach nearer than their fixed limits. *Flexibility* is a variation of toughness, and is here opposed to *elasticity*. A mineral is said to be flexible when it not only bends but remains bent, as talc; while an elastic one, as mica, not only bends, but when at liberty returns to its natural position. In a flexible substance, therefore, the original particles are removed from their situations without yielding any part of their attractions or repulsions; that is, without being removed beyond the limits of attraction, or compressed within the limits of repulsion, for as they change place they are still attracted by others. In an elastic body when bent, some particles are removed beyond the limits which they occupy in the substance at rest; and yet are not beyond the limits at which they cease to attract; and others are compressed within the limits of re-

pulsion, when the repulsion becomes greater, (see GRAVITATION, Chap, XIV.) and, therefore, when the bending force is removed, the substance will return to its natural position, and the particles will return to the limits at which attraction and repulsion are nearer to balancing each other. The particles therefore, of the flexible substance change situation with respect to each other, and the removed particles form new relations; this is not the case in elastic substances; the mutual relations remain the same, and the struggle of the particles to regain their specific distances, is, the cause of the elasticity.

Specific Gravity. From the above remarks, the reader will readily understand, why a crystalline substance requires more space than one uncrystallized; as, for instance, why ice should fill one-fifteenth more space than its water; and why there should be a difference in there specific gravity, notwithstanding a considerable loss of caloric. But the foundation of specific gravity, in general, is, in the intimacy of combination, or depends on the number of the definite proportions of the inherent electric fluids, which the combined elements have parted with. Thus, in Chap. IX., s. 6, we represented barytes as detaching sulphuric acid from all substances, and as parting with its tenth definite proportion of inherent electric fluids; accordingly we find sulphate of barytes possessing a greater specific gravity, than any other known earthly mineral, being 4·7, which is almost double that of the generality of such minerals. We also see, why a substance when hot should have less specific gravity than when cold, because the caloric arranges itself in the mass in the same manner, or with as much regularity as the inherent electric fluids are arranged. (See Light and Heat, Chap. XIV.)

Electricity. Many minerals by friction, or when heated become charged with the combined electricities; the fluids arranging themselves on the opposite sides or ends of the same crystal. This is another natural result of the polarities of the original molecules, and shews that the negative are arranged in one direction, and the positive in another. Now as the uncombined positive fluid shews a predilection for substances which contain the most oxygen, and the negative for those which contain the least, the positive fluid will arrange itself at the negative pole, and the negative at the positive. What must farther depend on these polarities of the original molecules,—the end that attracts the positive usually presents the greatest

number of faces. Those minerals, not excitable by heat, generally have their opposite ends and sides equal; but sometimes opposite sides exhibit electric phenomena.

Though in the above conjectures on crystallization, we supposed the integrant molecules suspended in a menstruum that permitted a freedom of motion; yet this is not absolutely necessary to the formation of crystals; for in a fused mass, there is reason to believe that the molecules assort themselves in the process of solidifying; but that they may solidify without crystallizing, or before they shoot into crystals. This seems proved by the experiments of Mr. G. Watt on a large mass of basalt; in which the formation of a radiated structure took place, and spherical forms were assumed after the mass became solid; and after many days small crystals began to appear in the stony substance: so that the change went on from glass, to a rock inclosing crystals. Glass, when kept for some time at a heat just short of fusion, becomes crystalline, or assumes a granular or fibrous structure, and thus forms what is called Reaumur's *porcelain*. With the assistance, therefore, of vast charges and discharges of electricity, may granite have assumed its crystalline state, like the consolidating basalt; and like the glass, may all the imbeded, but generally apparently comminuted crystals of the older rocks, have been formed; while the sparry or stalactitic crystals, with their feathery and fantastic forms, or, occasionally filling the whole of the cavity, whether a mere crevice, a rent or vein, entirely full, were formed by the assistance of water or sublimation.

CHAP. XIII.

The Metals.

1. REMARKS.

The general characteristics of the metals, are, hardness, tenacity, lustre, opacity, fusibility, malleability, ductility, great specific gravity, superior power of conducting heat and the electric fluids, and, when in oxides, a capability of uniting with the acids and with them forming metallic salts; also, after being fused by heat and left to cool slowly and quietly, they crystallize mostly in octohedrons, which is the general form of the crystal in such as are found native. They are 28 in number, though only 7 were known to the ancients; viz. gold, silver, mercury, copper, iron, tin and lead. They are the great agents by which man is enabled to explore the bowels of earth, examine the recesses of nature, and form almost every instrument of manual occupation. In short the manufacture of the metals, is the chief badge of civilized life, since savages have never been occupied therewith.

They are generally taken from the bowels of the earth, either in a state of combination with other metals, with sulphur, with oxygen or with the acids; though specimens of some few are frequently met with in a state of purity: when they are said to

be *native*. There are various modes of separating them from their ores; such as, washing, roasting, fusion; though this is principally in the large way; others must be separated by forming amalgams; and the acids not only form chemical tests to ascertain what metals are present in ores, but certain of them, even in the large way, are only to be dissolved or separated by their agency. Were it not for the art of pouring a concentration of oxygen upon them in the form of an acid, and thus reducing them to that state most fit for the purpose, some of the metals of the greatest service in the arts would be of no use.

The metals may be divided into 4 classes. 1. Those which absorb oxygen and decompose water at a high temperature, viz. iron, tin, zinc, and manganese. 2. Those which absorb oxygen at different temperatures, but do not decompose water at any temperature: they are osmium, cerium, tellurium, titanium, uranium, nickel, cobalt, copper, lead, antimony, bismuth, and mercury: but the first five, on account of their having been found in very small quantities, have not yet been applied to any use. 3. The metals which do not decompose water, but absorb oxygen, and are thereby converted into acids, they are arsenic, molybdenum, tungsten, chromium and columbium. 4. Those which do not decompose water, nor absorb oxygen from the atmosphere at any temperature, viz. platina, gold, silver, palladium, rhodium and irridium.

2. IRON.

34·5 iron .. 10 oxygen, green or black oxide, being the scales from hot iron.
34·5 iron .. 15 oxygen, red oxide, or rust of iron, but common rust is always saturated with carbonic acid.

Specific gravity 7·7.

PURE Iron is of a bluish grey colour, has a granular texture, is very hard, less malleable than gold, silver, or copper, but more ductile, and is the most elastic of all the metals. It fuses with difficulty by heat, but is soluble in the acids, and then has a disagreeable taste. It emits a peculiar smell when strongly rubbed, is attracted by the magnet, and will under certain circumstances become magnetic itself. It also gives more brilliant sparks than can by any other means be obtained by the collision of flint; and is the only metal, except platina and

sodium, that can be welded. It is the most useful and most abundant of all the metals, being universally diffused throughout nature, as well in the vegetable and animal kingdoms as in the mineral. Besides, it is seldom an unobserved ingredient; being the substance Nature generally uses to give colour to her productions. With it she reddens the common brick, and blends the beautiful hues of the precious stone, viz. black in the obsidian, green in the euclase, blue in the lazulite, red in the garnet and ruby, yellow in the topaz, brown in the tourmaline, and it preserves the somnite a perfect white. She is no less fanciful with it in the vegetable kingdom, for with the oxide of iron she is supposed to spread her variegated tints in the flowers; and in the animal kingdom, she with it gives colour to the blood. She has in some measure also ordained it the badge of civilized life; for, where iron has not been in use, there has man invariably led the savage life of a wild beast. It also has various uses in medicine, and is said to be the only metal that is innoxious.

Cast Iron.—Iron is an ingredient of almost every rock, from the oldest primary to the newest alluvial; it occurs in combination with sulphur, but in most other cases it is in the state of oxide, and is thus combined with titanium, manganese and chrome; with the phosphoric, sulphuric, carbonic, muriatic, and arsenic acids; but the ores chiefly used in England contain silex, alumine and lime. They are broken into small pieces and put into the blast, which is made somewhat in the form of a common brick-kiln. The lower part is filled with fuel, principally coke, then a layer or basket of ore is put in, and one of lime for a flux; these, and more coke are added alternately till the blast is filled. The whole is then lighted, and a bellows worked by a steam engine raises it to a most intense heat. The part near the bellows is fused, and falls into the vacuum at the bottom caused by the consumed fuel; more comes in immediate contact with the blast of the bellows and is melted in its turn, while they keep loading on the top till a great part of the cavity is full of the fused materials. At the bottom of the blast is a small orifice slightly stopped with clay, which the workman perforates, and the liquid metal rushes out in a fine brilliant stream, with the dross after it. It is, now, pig or *Cast Iron*, and contains about a forty-fifth part of carbon, but is rendered brittle by the presence of oxygen, phosphorous and silicium. These materials make it considerably more fusible than pure

iron or steel; hence its use in a great variety of manufactures. From the nature of iron, rather expanding than shrinking in cooling, more perfect casts can be obtained of it than of any other metal.

Forged Iron, is iron in the purest state; and is made from cast iron by keeping it a considerable time in a state of fusion, when the oxygen and carbon form carbonic acid and fly off. It at length assumes a stiff pasty consistency, which is the signal for the workmen to withdraw it, and submit it to frequent hammering, when the silicium and other impurities are pressed out. It is now rendered malleable, ductile, and almost infusible. If it still retain phosphorus, it is somewhat brittle, or of an inferior quality; breaks with a white lustre, and is called hot short, to distinguish it from another kind called cold short, which is supposed to contain silicium. When iron is heated to redness and plunged into cold water, it decomposes the water and imbibes the oxygen, which makes it hard and brittle; though these properties are otherwise accounted for, viz. by the iron being crystallized,

Steel is made by covering the best forged iron in a bed of powdered charcoal, and exposing the whole to an intense heat for ten or twelve days, the air being totally excluded. By this means the pure iron absorbs about a two-hundredth part of its own weight of pure carbon from the charcoal, and this combination is the best steel. *Cast Steel* is manufactured by fusing iron in carbonate of lime. It contains more carbon than common steel, and is much more fusible. If a diamond be inclosed in a slip of iron and exposed to a white heat, it will disappear and excellent steel will be the result. If a piece of forged iron be dipt into cast iron while in fusion, it will imbibe carbon and its surface will become steel: several articles are thus manufactured, and the process is called *case-hardening*. Different tempers are given to all kinds of steel instruments, or edge-tools, by heating them to fixed and certain temperatures, in mixtures of fused metals and then cooling them in various ways. Good steel may be known from iron in any instrument by letting fall a drop of nitric acid upon it. If it is steel there will be a black spot, but not if it be only iron: this phenomenon is supposed to depend upon the iron's being dissolved and the carbon's being left naked. A finer wire may be drawn from tempered steel than from any other metal. A wire one tenth of an inch diameter made of iron will support a weight of 450 lbs; but one

of the same thickness of tempered steel will carry without breaking 900lbs. By repeated hammering steel will become forged iron.

MINERALS.—Mineralogists enumerate about 23 principal ores of iron, each of them including varieties; but the chief of them seems to be the *Oxydulated Iron* or *Native Loadstone.* It consists of 24·14 green oxide and 71·86 red oxide, its specific gravity is 4·4, it is highly magnetic especially the massive found in Sweden, Norway and China. It occurs earthy, compact, lamellar and crystallized, in regular octohedrons, its colour is iron black with a shining glimmering lustre. It chiefly belongs to primary mountains, and generally occurs in beds and large masses accompanied by hornblende, granular limestone, garnet, and occasionally by all the varieties of pyrites, fluate of lime and oxide of tin. There are said to be whole mountains of it in Sweden and Chili, the granite mountains, extending most of the way from New York to Canada contain large beds. It abounds in Corsica, Savoy, Saxony, Bohemia, Silesia, Russia, and the East Indies. It occurs also in Devonshire and Cornwall, in Unst one of the Shetland isles, in Ireland in granite, and along with native gold in alluvium. That of Sweden is highly valued by the manufacturers of steel.

Specular Iron consists chiefly of the red oxide, it occurs lamellar and crystallized—the latter is magnetic, both in beds and veins in primary and transition rocks. The mines of Elba are the most noted, but it occurs in Cornwall, Lancashire, Cumberland, Scotland and various parts of the world: occasionally in the lavas of volcanoes.

Native Iron occurs at Kamsdorf, Saxony 92·5 iron, 6 lead 1·5 copper. It is chiefly met with in veins. Arsenical iron, including a number of varieties also occurs in veins 58·9 iron, 42·1 arsenic. One variety contains 13 per cent. of silver and 4 antimony: it sometimes contains gold.

The Hæmatites, or red, brown and black iron ores, are the most prized of the British ores. One specimen of red consists of 90 oxide, 2 silex, 3 water, 1 lime, and a trace of manganese. It occurs in beds and veins in primitive and secondary mountains. That of Ulverstone, Lancashire is the most noted.

3. TIN.

$$100 \text{ Tin} \begin{cases} 13{\cdot}5 \text{ Oxygen} & . \text{ Yellow Oxide} \\ 27{\cdot}0 \text{ Do.} & . \text{ White Oxide} \end{cases}$$

Specific Gravity 7·291

TIN is a white metal, having little elasticity, ductility, or hardness, though it is harder, more ductile and more tenacious, than lead. It is very fusible, and makes a peculiar cracking noise when suddenly bent. It emits a peculiar smell when rubbed, and is more combustible than most of the metals, burning in oxygen gas before it arrives at a heat sufficient to fuse it. It is abundantly and almost exclusively found in veins passing through primitive rocks, especially granite and clayslate.

Tin has various uses in the arts. The ancients generally combined it with copper; coins and other articles are frequently found of this alloy. The greatest consumption of tin is in covering sheet iron. The sheets are thoroughly cleaned, and steeped for 24 hours in water acidulated with bran or sulphuric acid. They are then dried, rubbed over with grease, heated in an oven, and afterwards immersed in melted tin, which not only coats the surface but penetrates the iron. They are the sheets which we generally buy under the name of tin, and of which a great many culinary and other utensils are made. Pins are also coated with tin. They are made of brass wire which contains a great deal of zinc, for which metal tin has a great affinity. A pan is filled with a layer of pins, and one of grain tin alternately; supertartrate of potas is then poured upon them, and they are boiled together for 4 or 5 hours, when the acid dissolves the tin, and precipitates it upon the pins. *Pewter* is generally composed of 112 tin, 15 lead, and 6 brass. Large quantities of tin are also used by the dyers, particularly with cochineal, and archil to give brightness and stability to reds and scarlets: for this purpose it is dissolved in a peculiar kind of aqua-fortis called *Dyer's Spirits.* Tin combines in two degrees with sulphur, viz. 100 tin, 27½ and 55 sulphur. The former is a bluish substance with a lamellated texture; the latter is of a bright golden colour in light soft flakes. It was formerly known by the name of *Aurum Musivium* or Mosaic gold, and is by some supposed to have been the phantom which illuded the alchemists in their search for gold. This metal also unites in two

proportions with chlorine: 55 tin, 13·5 and 67·5 chlorine: the latter combination is called *Liquor of Libavius.*

MINERALS. The tin-mines of Cornwall have been worked for two or three thousand years: and we are assured, that, so long ago, the British tin found its way into all the flourishing states of the East. The Tyrians and Phœnicians or Phillistines traded in it. From the Cornish mines alone are now annually raised 3,000 tons. There are mines also in Devonshire, and it is found in small quantities in various other parts of England. Tin mines are likewise worked in Germany, Saxony, the East Indies, and in South America: that from the last country is said to be the best, but a duty of 30 per cent. prohibits its use in this country. Tin occurs chiefly in oxide combined with small portions of oxide of iron and silex, generally crystallized, rarely in mass. It is sometimes found in alluvial deposits in small detached rounded pieces, chiefly in the low grounds and marshy places in Cornwall—sometimes accompanied by grains of native gold. That in veins is occasionally fibrous and granular, but mostly crystallized, coating cavities or disseminated among a variety of other minerals. A quadrangular prism terminated by four sided pyramids, is the most common form:—it consists of 77·5 tin, 21·5 oxygen, 0·25 oxide of iron, 0·75 silex. A *sulphuret* also occurs in Cornwall, 34 tin, 36 copper, 25 sulphur, and 2 iron.

4. ZINC.

80·39 Zinc, 19·61 Oxygen,—White oxide. Specific Gravity 6·861.

ZINC is considered as one of the most abundant metals. It is a shining, bluish white metal; but when exposed to the air, from its great affinity for oxygen and carbonic acid, it soon becomes covered with a thin pellicle that reflects various colours. It is so combustible that thin leaves will inflame at a candle, and on this account its filings are used in fire-works for producing those beautiful stars and spangles which they often exhibit. It seems to form the link between the brittle and the malleable and ductile metals. It melts at 680 degrees, at a stronger heat it becomes volatile, and is extracted from its ores by distillation; at a white heat it absorbs oxygen so rapidly, that the oxide sublimes, and is collected and sold as *flowers of zinc.* This metal is readily acted on by the acids, and by their

agency will decompose water, absorbing the oxygen, whence more pure hydrogen gas can be obtained than by any other means.

Zinc abounds in China, and in its purest state, it there constitutes the current coin. The pieces have a square hole in the middle that they may be carried on a string, and are stamped with Chinese characters on one side and with Tartar on the other. In England it is generally used with the alloys of copper, though it has been used alone instead of lead for making water spouts :—the workmen generally call it *Spelter*. From its so readily oxiding, it is of great use in galvanic electricity, and its amalgam is the best for coating the electrifying machine. The oxide or *flowers* of zinc, is extremely light and has the appearance of fine wool; it has been used instead of white lead in house painting. The oxide, sulphate, and acetate are used in medicine; the last is recommended in inflammatory cases.

MINERALS.—Zinc occurs in combination with sulphur, oxygen, the carbonic or sulphuric acids, also with oxide of iron, silex and water. Its ores are not numerous, and have rather an earthy than a metalliferous appearance. It chiefly occurs in the lead and copper mines. Blende is a sulphuret, and occurs crystallized and amorphous, the forms of the crystals are numerous, and the structure is lamellar. It consists of 68·48 zinc, 23·16 sulphur, 8·08 iron: but the varieties differ in composition, some contain silex. *Calamine* is both crystalline and massive,—the former 65 oxide of zinc, and 35 carbonic acid; but the proportions in the latter are 71 and 13½: some varieties contain silex and water. Sulphate of zinc, called also white vitriol is found in mineral waters at Holywell, Flintshire; here the sulphuret is called *black-jack*, and is so abundant that it was lately used in repairing the roads. The native oxide chiefly occurs in New Jersey, America.

5. MANGANESE.

100 Metal $\begin{cases} 26\frac{1}{3} \text{ Oxygen, . Olive oxide} \\ 39\frac{1}{4} \text{ Oxygen, . Dark brown or black} \end{cases}$

Specific Gravity 7 or 8.

THIS is a brilliant metal, of a darkish white or rather greyish colour; it is very brittle, of considerable hardness, and not easily fused, but it is not much known, its attraction for oxy-

gen being so great that, when exposed to the air, it quickly falls into powder or becomes oxydized; in this state only it is found in nature, and is almost universally diffused, though but in small quantity, through the mineral kingdom, especially in soils; it also occurs in the vegetable and animal kingdoms.

The black oxide is much used by chemists in procuring oxygen gas;—at a red heat it gives out 14 per cent., but will by heat part with no more. This oxide gives a violet colour to glass and porcelain, and the amethyst, and rubellite or red-tourmaline are tinged with it. It is also used in purifying glass and the precious metals. Mixed with three times its weight of nitre and thrown into a red hot iron vessel, a curious, greenish powder is produced, called *Mineral Cameleon.* If a little of it is thrown into a glass of water, it is first blue: then the yellow oxide of iron separates, and it is green; the oxide falls to the bottom, and it is blue again; the manganese then begins to absorb oxygen from the atmosphere, and the mixture becomes reddish, brownish, and at last black; it then falls to the bottom and the fluid is colourless. Again, if hot water be poured upon this, there will be a beautiful green; but if cold, a deep purple

MINERALS.—Manganese occurs in the proportion of 1·4 per cent. in mica a constituent of granite. There are about 6 principal ores with varieties, and they occur both in primary and secondary formations, that called the *grey oxide* seems to be the chief, containing about 90·5 black oxide, 2·25 oxygen, and 7 water: it occurs in veins, beds, and irregular masses. A variety contains barytes, carbon and silex. Other minerals contain silex, lime and magnesia. There are also sulphates, carbonates, and phosphates of manganese. Most of them occur both crystallized and massive.

6. OSMIUM.

THIS is a dark blue metal, very hard, insoluble in the acids, infusible and even unchangeable by heat, unless exposed to the air, when it combines with oxygen and evaporates, producing a peculiar smell differing from any thing known of. This vapour is its oxide, which is a sweet tasted, colourless, semitransparent substance. It will solidify, will dissolve in water, and with potas form an orange coloured solution; with ammonia, a yellow; with lime, a bright yellow; with an infusion of gall, a

purple, which passes into a deep bright blue; and with alcohol or ether, a black. It also imparts to the skin an indelible, dark coloured stain. The metal readily fuses with copper or gold, and with them forms a malleable alloy. It was first discovered in the dross of platina, but a distinct ore has since been found, though alloyed with irridium and platina. The specific gravity of this ore is 19·5, and it is only found in South America.

7. CERIUM.

100 Metal { 17·41 Oxygen . White oxide
26·11 Oxygen . Red oxide

The quantity found of this metal is so small, that very little is known respecting it, except that it is harder, whiter, much more brittle, and more scaly in its fracture than cast iron, and volatile at a great heat.

MINERALS.—Its two chief ores are the *cerite* and *allanite*. The former occurs among the copper pyrites in Sweden, and contains 54·5 oxide; the latter contains 53·9 per cent. and occurs in a granite rock in West Greenland. The other ingredients are silex, lime, oxide of iron and water; the former contains carbonic acid and the latter alumine. The orthite 3.44 white oxide, the yttrocerite 20·22 fluate;—there are other three minerals also, chiefly composed of fluate of cerium.

8. TELLURIUM.

83 Metal, 17· Oxygen. Specific Gravity 6·115.

TELLURIUM is a white metal, of considerable lustre; very fusible, volatile at an intense red heat, and soluble in nitric acid and chlorine. When heated in atmospheric air, it burns with a pale blue flame, edged with green, and is then converted into an oxide, which is white, but tinged with yellow, and is soluble in the acids. The metal combines with sulphur, likewise with hydrogen in two proportions, one of them an acid. Also with potassium and sodium, emitting light and heat, and forming alloys almost infusible, which, when thrown on water, produce purple solutions.

Minerals.—It is an extremely rare metal, having been found only in Transylvania, whence it is sometimes called Sylvan. It occurs only in the metallic state, but always alloyed in different proportions with other metals: its ores are only four in number, and very rare.

Native Tellurium, 99·55 tel., 7·2 iron, 0·25 gold
Graphic, 60· tel., 30· gold, 10 silver
Yellow, 44·75 tel., 26·75 gold, 8·5 silver, 19·5 lead, 0·5 sulphur
Black, 32·2 tel., 54 lead, 9 gold, 0·5 silver, 1·3 copper, 3 sulphur.

They occur in veins of porphyry, with native gold, quartz, and other minerals.

9. TITANIUM.

89 Metal	Not known,	.	Blue
	Not known,	.	Red, found native
	10 Oxygen,	.	White

This metal is somewhat of the copper colour, has considerable lustre, but soon tarnishes when exposed to the air. It is brittle and almost infusible, combines with iron, and forms an alloy utterly infusible. Little more is known of its properties, and it is a rare metal.

Minerals.—There are about 7 minerals with a few varieties wherein an oxide of this metal is a chief ingredient. Most of them are found in Scotland, some in Cornwall, principally in granite. Iserine, consisting of 48 oxide of titanium, 48 oxide of iron, and 4 oxide of uranium, has been found on the shore of the Mersey opposite to Liverpool, oozing out of a bed of magnetic iron sand beneath a bank of clay.

10. URANIUM.

80 Metal	6·6 Oxygen,	.	Black
	20·0 Oxygen,	.	Yellow

Specific Gravity 6.

The colour of uranium resembles that of iron, though internally it is somewhat of a reddish brown. It possesses considerable lustre, and does not tarnish when exposed to the air at the usual atmospheric temperature. It is hard and brittle,

difficult of fusion, combines with sulphur and dissolves in nitric acid. The yellow oxide gives a lasting deep orange yellow to china, imparts to glass, green, and brown colours; produces beautifully transparent green oblong crystals when dissolved in weak nitric acid; and when in acetic acid, topaz yellow coloured crystals: it is a rare metal.

MINERALS.—Its ores are only two in number. *Uran Ochre*, or Pitchblende, 86·5 oxide, 6 galena, 2·5 green oxide of iron, 5 silex. *Uranite*, a phosphate, 60 oxide, 9 oxide of copper, 15·3 phosphoric acid, 13·8 water, 0·5 silex, 1·4 loss. They occur in Cornwall and the latter in several other parts of the world.

11. NICKEL.

27·30 Oxygen, . . Green oxide
40·95 Oxygen, . Black or Brown

Specific Gravity 8·38; hammered 8·932.

NICKEL is a fine brilliantly white metal, susceptible of a beautiful polish, and does not lose its lustre when exposed to the air, unless ignited, and then assumes a bronze colour. It has great tenacity, ductility, and malleability; is nearly as hard as iron, as difficult of fusion, and possesses the magnetic powers almost in as high a degree of perfection as that metal. However, arsenic, with which this metal is frequently found combined and from which it cannot well be separated, totally destroys its magnetic properties. When exposed to the air at an intense heat, it is converted into the brown oxide, which is still magnetic. This oxide gives a delicate grass green to porcelain, and to flint glass a hyacinthine colour; it dissolves in ammonia and produces a pale blue colour. The metal dissolves in many of the acids and gives to them a green colour. With iron it forms a useful alloy, that receives a fine polish and does not tarnish so soon as iron alone; another with brass, is much used by the Chinese in making toys: they also make with it a beautiful metallic compound called *white copper*.

MINERALS. Nickel is a rare metal. It sometimes occurs native in the cavities of its principal ore, *Copper Nickel*. It is capillary, with occasionally diverging filaments, of a yellowish colour inclining to steel grey, but on account of its containing a little arsenic is not magnetic. *Copper* or *Arsenical* Nickel,

is a copper or yellowish red with various shades, but tarnishes by exposure. One specimen consisted of 44·2 nickel with a little cobalt, 54·7 arsenic, 0·3 iron, 0·3 lead, 0·4 sulphur. It is generally accompanied by ores of cobalt, silver, and copper, and mostly occurs in veins of primitive rocks, but occasionally both in transition and secondary in Cornwall, Scotland, several parts of the European Continent and in North America. *Arseniate* of Nickel or *Nickel Ochre* usually encrusts or adheres to the above, from which it differs a little in composition. Pimelite contains 15·62 oxide, occurs in veins of serpentine along with chrysoprase, to which nickel is supposed to give the colour. They are found in Silesia.

12. COBALT.

100 Metal { 27·3 Oxygen . Blue
40·95 Oxygen . Black }

Specific Gravity 8·7.

COBALT is of a light grey colour, nearly resembling polished steel, with a reddish cast. It is harder than copper, so brittle that it may be reduced to powder, suffers little change when exposed to the air at the usual temperatures, is difficult of fusion, burns brilliantly when fused over charcoal with a stream of oxygen gas, and in a small degree possesses the magnetic properties.

This metal is much employed in the arts, chiefly on account of the fine blue colour which it imparts. The oxide has great intensity of colour, and is called *Zaffre.* When melted with 3 silex and 1 potas, it forms a blue glass, which when pounded is called *Smalts.* It is of inestimable value in the manufacture of porcelain, both for the beauty of its colour, and its durability in the highest temperatures of firing. *Strewing* smalt, used by sign painters, is Zaffre fused with 240 flint glass, and ground to a coarse powder. *Powder* blue used by laundresses is the same ground very fine. It is also used to give a tinge to white paper, and it forms the basis of many pigments. The oxide is said to have been used by the ancient Painters: hence their skies and draperies of unfaded blue.

Hellot's sympathetic Ink is diluted muriate of cobalt. Writing of this ink, while kept cold, remains invisible; but if warmed, assumes a beautiful blue. If a little iron be in it, the

letters will be a fine lively green. With these two inks a picture of winter may be drawn, which, when held to the fire, will assume the bloom of summer; and when again removed to the cold, will lay aside its verdure, and appear in its winter hues. This may be further variegated with the acetate of cobalt, which is red; but when warmed, is blue.

MINERALS. Cobalt is not an abundant metal; its ores are only about five with varieties, but occur in veins of both primary and secondary mountains, mostly accompanied by the ores of copper, sometimes by those of silver, native silver, native bismuth, native arsenic, but it never occurs native itself: it is generally combined with nickel and arsenic, the latter rendering it extremely pernicious in the art of refining. White cobalt, 44 cobalt, 55· arsenic, 0·5 sulphur, is found in veins and imbedded in mica-slate and gneis, in Norway, Sweden, and Silesia, and affords the principal part of that of commerce. *Grey* Cobalt, containing a little iron occurs in many places on the continent, at Chatham, Connecticut, North America, and in several mines in Cornwall; it is mostly accompanied by *Tin-white Cobalt*, which contains a trace of copper. Earthy cobalt occurs at Alderley-edge, Cheshire, in Cornwall, Ireland, and on the Continent. *Red-cobalt*, is also found in Cornwall, in several parts of Scotland, and on the East of Ireland. Sulphuret, and sulphate of cobalt, or red vitriol, occur in Sweden. Till the diffusion of chemical knowledge the cobaltic ores of Hesse were used for repairing roads, and the miners considered them so troublesome, that they used to pray to be delivered from cobalt and from evil spirits; but these ores now afford a considerable revenue. However cobalt is now extracted from the ores found in Cornwall.

13. COPPER.

$$100 \text{ Metal} \begin{cases} 12\frac{1}{2} \text{ Oxygen} & . \text{ Red oxide} \\ 25 \text{ Do.} & . \text{ Black oxid} \end{cases}$$

Specific Gravity 8 or 9.

COPPER is a brilliant, red coloured metal. It emits an unpleasant smell when rubbed, and has an extremely nauseous taste. It is very hard, elastic, and the most sonorous of all the metals, only exceeded by gold in ductility, and in tenacity by iron. Its malleability is such, that it may be hammered into

leaves like gold. It melts at a white heat, and burns when acted upon by a stream of oxygen gas with a red flame, edged and tipt with green. It is only exceeded by iron in abundance, and usefulness. Besides two combinations with chlorine it unites with iodine, likewise with sulphur and phosphorus. It occurs in a pure or native state; also combined with iron, antimony, silver, and arsenic; likewise mineralized by oxygen, sulphur, and by the carbonic, muriatic, phosphoric and arsenic acids. Its ores often occur in the same vein with those of tin in Cornwall, but the copper is generally found beneath the tin, and where veins intersect each other those of copper cut through and displace the tin.

In Sweden houses are covered with copper, and ships are sheathed with it in England, besides its employment in making boilers and other vessels. It is less combustible or not so apt to strike fire as iron, and is therefore preferable for machinery in gunpowder mills. On account of its great elasticity, it is used by rope-dancers; and its being sonorous causes it to be employed in trumpets and other musical instruments. When beat into leaves, it is called Duch metal; and is employed for covering toys, and for several other useful purposes. Its tenacity is such, that a wire of one tenth of an inch diameter will support a weight of 300 lbs. It forms many useful alloys with other metals. Brass is 3 copper and 1 calamine (zinc ore) fused together. *Pinchbeck*, 5 or 6 copper to 1 zinc; it is an imitation of gold. *Tomlac* has more copper and is of a deeper red, arsenic is sometimes added, and it is then called *white* copper. Prince's or Prince Rupert's metal contains more zinc than either of the last two. Copper, tin and zinc form bronze. Gun metal 100 copper and 10 or 12 tin. Bell metal is usually 3 copper to one tin, An alloy of 2 copper and 1 tin formed the mirrors of the ancients, and is now used for the specula of reflecting telescopes. Copper also combines with nickel, manganese, iron and lead.

The oxide is used in staining glass, to which it gives a beautiful green colour: the salts of copper are many and their uses various. The comon *blue* vitriol, or as it is sometimes called *Roman vitriol*, is a sulphate of copper, and is used by dyers; a solution of it gives a brown colour to tea urns and fowling pieces: it consists of 32 black oxide, 32 sulphuric acid, and 36 water. *Mineral green* is a sulphate precipitated by caustic potas and arsenic. *Verdigris* is an acetate. *Blue Virditer*, used

in staining paper for hanging rooms is a carbonate with lime water. *Scheele's green* is copper and arsenic. *Brunswick green*, copper, potas and tartaric acid. Vegetable acids and fat do not act upon copper while hot; but if they are suffered to remain till they are cold in culinary vessels of this metal, a bluish green crust or salt is rapidly formed, which is poisonous in the highest degree, and has often caused fatal accidents.

MINERALS. Copper is found in all parts of the world, and in all the rock formations from the granite to the magnesian Limestone. Between Kamtschatka and Japan are islands consisting almost entirely of native copper;—it also abounds in China, Japan, Sumatra, and several of the islands in that part of the world. Masses of native copper are frequently found lying on the surface in Brazil and Chili, one mass in the former country, lying in a valley, weighed 2,666 lbs. It abounds in the copper mountains near the polar seas, North America. Native copper is also frequently met with in the mines of Sweden, Hungary, Cornwall, Anglesea, Isle of Man, and in some parts of France. It is generally of a red colour, but sometimes black or brown; and some specimens are of various colours and very beautiful. The copper mines in Sweden are subterraneous towns; people are born in them and seldom visit the surface of the earth. The mines of Anglesea once yielded annually more than 20,000 tons, the vein was 70 feet thick: yet, Cornwall is considered the greatest deposit of copper hitherto found. The ores occur principally in the tin mines, and were formerly thrown aside till chemistry taught how to separate the metal. The workmen have a ready and sure mode of ascertaining whether there is copper in any fossil they meet with: they drop a little nitric acid upon it, and then, with a feather, place a little of the solution on a knife blade; and if it contain the least copper it is precipited.

The *ores* of copper are about 18 in number. *Sulphuret* of, or *vitreous* copper consisting of about 80 copper and 20 sulphur, occurs in nearly all the mines. A small vein was worked at Middleton Tyas, Yorkshire, in the Magnesian Limestone, whence it was traced almost due west through an outskirt of the sandstone of the independant coal-formation, towards the milstone grit and mountain limestone of the lead mine districts. Copper pyrites, or yellow copper is the most abundant ore of copper, especially in the Cornish mines: it consists of about 30 copper, 32·20 iron, 35·16 sulphur, with a little lead, arsenic and earthy matter.

14. LEAD.

100 Metal	7·7	Oxygen	. Yellow oxide
	11·08	Do.	. Red
	16·6	Do.	. Brown

Specific Gravity 11·35.

Lead is a bluish-grey metal, very brilliant when cut, but soon tarnishes when exposed to the air. It emits a peculiar smell when violently rubbed, readily dissolves in the acids, and imparts to them a sweetish taste, but the productions are very poisonous. It is the softest of all the metals, very malleable, is ductile, but has so little tenacity that it soils the fingers when handled, and readily marks writing paper. It has little elasticity and is therefore scarcely sonorous, and its specific gravity is diminished by hammering. It almost always occurs combined with a little silver, that found in primitive slate contains 8 or 9 per cent. It is nearly equal to zinc or copper (some say next to iron) in abundance, and is one of the most useful of metals.

When lead is melted in an iron vessel exposed to a blast of air, it is quickly covered with a scum ar coat of oxide; this coat is removed, and another is immediately formed till the whole of the lead is oxydized, while the silver remains behind in the vessel. This oxide is called litharge, and is partly vitrified and scaly; but on being exposed to an intense heat, the oxygen is dispersed and the lead remains pure. But if it is exposed to a gentle heat in contact with the atmospheric air, it imbibes more oxygen and becomes the *yellow* oxide or *massicot.* If a stronger heat is continued for 48 hours with constant stirring, it is converted into the red oxide; a still larger doze of oxygen forms the brown or pure oxygen. common litharge is chiefly the fumes from smelting, collected in the flues. The oxides of lead are used in manufacturing the finer kinds of glass for the purpose of making it less brittle, more refrangible of the rays of light, and susceptible of a higher polish; but such glass is also more soft and liable to be scratched. They are also used as red and yellow paints; likewise in dyeing, calico-printing, in various pigments and for a variety of useful purposes. *Turner's* or *Patent yellow* is a muriate fused in earthen crucibles.

White Lead or common white paint is a carbonate of lead. It is made by exposing thin sheets of lead a long time to the

warm fumes of vegetable acids. This is the poisonous substance produced by improving the taste of wine with lead, making cyder in leaden vats, or by keeping water exposed to the air in leaden reservoirs: in all which cases it has occasioned infinite mischief. It extracts the rancidity from oil, and corrects the rauciness or acidity of wine; in the former case it may be precipitated, but in the latter it remains in the fluid. Wine-merchants have been known to use it, and thus furnish to their customers a deadly poison; and indeed the ancients sometimes improved the tastes of their wines by dipping leaden plates in them. Water alone will not corrode lead, but when in contact with the atmospheric air, it attracts carbonic acid around the surface of the water and this salt is formed, and renders the contents of the reservoir poisonous.

Lead is used to purify the precious metals, for it will combine with gold or silver at a moderate heat; but when the heat is much increased the lead rises to the surface combined with all the heterogeneous substances, leaving the precious metal purified below. Combined with tin, it forms soft solder, with one fourth its weight of antimony, it composes printer's types for the large letters; it also forms useful alloys with cobalt, bismuth, mercury, platina, iron, zinc and copper.

MINERALS. The ores of lead are very numerous, and present a variety of appearances, often exhibiting an earthy aspect. It occurs combined with sulphur, with oxygen, with the carbonic, muriatic, phosphoric, arsenic, molybdic, and chromic acids; also with antimony, iron, manganese, and silver, or their ores; likewise with the earths silex, alumine, lime, magnesia and with water. *Galena*, lead glance, or sulphuret of lead, 85·13 lead, 13·02 sulphur, 0·5 iron is the most abundant of its ores, and occurs in all the British mines. There are 5 or 6 varieties of it, and it affords nearly all the lead that Great Britain produces, which is annually from 45 to 48,000 tons. The other minerals are about 17 in number, most of them containing several varieties, and nearly all of them occur in England. But lead abounds in nearly all parts of the world.

15. ANTIMONY.

100 Metal	18·6	Oxygen	.	Grey oxide
	27·7	Do.	.	White
	35·556	Do.	.	Yellow

Specific Gravity 6·8.

ANTIMONY is a brilliant, silvery white coloured metal, with a bluish shade, and suffers very little in its lustre by exposure to the air. It is apparently hard, yet is very easily cut with a knife; when rubbed on the hand, imparts a peculiar smell, is entirely destitute of ductility, and possessed of so little tenacity that it may be easily reduced to powder, which when thrown into chlorine gas immediately inflames, burning very rapidly with a brilliantly white flame. It melts at 810 degrees, expands while cooling, and forms crystalline pyramids with a laminated structure. It volatilizes at a great heat, and may be vitrified, forming a hyacinthine coloured glass. What is sold in the shops by the name of antimony is only a sulphuret, containing 25 per cent. of sulphur: the pure metal is generally called *Regulus* of Antimony. Its oxides in some solutions are very poisonous, yet, perhaps no metal is more extensively used in medicine.

Antimony combines with other metals to form the specula of telescopes, it also enters into the composition of printers' types. Its white oxide, once called Argentine flowers of antimony, is now called antimonious acid; and with the slight variation of being dipped in water, becomes *Powder of Algaroth.* The yellow is antimoniac acid. *James' powder* is a phosphate of lime and antimony. *Emetic tartar,* consists of 56 tartrate of antimony, 36 tartrate of potas, and 8 water. *Kermes'* mineral and golden sulphur are both sulphurets made with potas: they and other preparations of antimony are much used in medicine for cattle. Sulphuret of antimony was much used in remote antiquity by the females for staining the eyebrows black. Butter of antimony is a muriate, composed of 54·88 antimony, 45·12 chlorine;—it occurs native in Bohemia.

MINERALS.—Antimony is not a very rare metal, though it is found in few mineral districts. It occurs native, alloyed with small portions of iron and silver, near Grenoble France, in Sweden, Mexico, and Connecticut; in this last country large

masses are exposed to the day. Some varieties of sulphurets occur in Cornwall, in Dumfriesshire, in many parts on the Continent and in South America.

16. BISMUTH.

90 Metal, 10 Oxygen. Specific Gravity 9·8.

BISMUTH is a reddish white coloured metal, retaining its lustre when immersed in water, but losing it when exposed to the air. It melts at the low temperature of 476 degrees, renders a great many alloys very fusible, expands more than any other metal while cooling, and forms paralellopiped crystals with a lamellar structure. It is moderately hard, but not ductile, and possesses so little malleability that it may with smart strokes of a hammer be pulverized. It has no taste or smell, volatilizes at a great heat, burns when ignited with a beautiful kind of lambent flame, and also inflames spontaneously when suspended in chlorine gas. Its specific gravity may be a little increased by careful hammering. It is not an abundant metal, and belongs exclusively to primary countries.

Bismuth among workmen goes by the name of *Tin-glass*. It is chiefly used in the alloy of which printers' small types are made; and to its property of expanding while cooling are we chiefly indebted for the well defined edges of the printed letters: the metal in casting and cooling tightly filling up the mould. Bismuth gives brilliancy and hardness to tin, and their alloy is very useful in making vessels of capacity. An alloy of 8 bismuth, 5 lead, and 3 tin will melt at a lower temperature than that of boiling water. For amusement, fine looking tea-spoons are made of it, which, when put into the hot tea, melt in the hand of the surprised and unwary spectator. If equal portions of zinc, lead, and bismuth are melted together, they may be kept in a state of fusion on paper by merely holding them over the flame of a candle. An alloy of bismuth and lead is so fusible that it has often been used to adulterate quicksilver. *Pearl-white* or magistery of bismuth is prepared from the oxide: it is used as a cosmetic and imparts a beautiful white to the skin; but should the borrowed charms come in contact with sulphuretted hydrogen gas, which often abounds in the smoke of coal fires, they immediately assume a tawny and ghastly hue. Pomatum prepared with the oxide is said to turn the

hair black. Nitrate of bismuth forms a *sympathetic ink:* the characters formed with it are invisible till the paper is plunged in water, when they become white and perfectly legible.

MINERALS.—Native bismuth occurs with the ores of cobalt, nickel, and sometimes with those of lead: it generally contains a little arsenic. It often occurs in feathery masses, both in Cornwall and other parts of the world. Along with it is generally found a *sulphuret (bismuth glance).* On the Continent the sulphuret often contains a large portion of copper, where also is found *bismuth* ochre or *oxide.* A carbonate occurs in Cornwall.

17. MERCURY OR QUICKSILVER.

100 Metal	4 Do.	.	Black oxide
	8 Oxygen	.	Red oxide

Specific Gravity of fluid 13·568; of solid 15·612.

THE peculiar feature of this metal, is, its continuing in a fluid state at the atmospheric temperature of our climate. It is white, and has the appearance and brilliancy of melted silver; imparts neither taste nor smell, and possesses the cohesive power so weakly that it may be pressed through leather. It does not oxidize when exposed to the air, unless agitated for a long time, or heated to 600 degrees. It boils at 656 deg. and is then gradually converted into an invisible and very elastic vapour. But when quicksilver is cooled down to 71 deg. below freezing point, it becomes as it were a new metal. It is then as solid and as opaque as other metals, tenacious, and so very malleable, that it may be hammered into sheets as thin as paper.

The *red* or bright scarlet oxide is obtained by heat, or by the agency of nitric acid, when prepared by this last method it is sometimes called *red precipitate.* When mercury is heated in chlorine gas, it burns with a faint red flame, and the product is *corrosive sublimate,* consisting of 74 mercury and 26 chlorine; it is soluble in water, has an acrid burning taste, and is a rank poison. *Calomel* is corrosive sublimate and mercury triturated together, and then submitted to sublimation. This is the most useful of all the preparations of mercury, but is dangerous; for unless well made, unless the corrosive sublimate is well dissolved, it is pernicious. Calomel is tasteless and insoluble in water; the best method, therefore, of proving that it contains

no corrosive sublimate, is, to boil it a long time in water, and if it remain undissolved and without taste, it is safe. Mercury also combines in two proportions with iodine, viz. 62½ and 125 iodine to 100 mercury. With sulphur it combines in two proportions, 8 and 16 sulphur to 100 mercury. The former is black and is Ethiops' mineral; the latter, by a particular preparation, is vermillion, which is made only by the Dutch and Chinese. Turbith's mineral is a sub-sulphate; and Keyser's pill an acetate.

But the greatest consumption of mercury is in South America in purifying the precious metals. It combines with most of the other metals and their alloys are called amalgams. When amalgamated with platina, the specific gravity of the compound is only 11½, though that of the platina alone is 21, and that of mercury itself above 13½. With bismuth it is used for coating the inside of glass globes; with tin for common mirrors; and with zinc for electrifying machines. A fulminating powder is made from this metal, recommended in blasting rocks, as its immediate effect is greater than that of gunpowder, though it does not extend so far.

MINERALS.—Mercury is an abundant metal, and it is found in various parts of Europe, Asia, and South America, though comparatively in few districts. It often occurs native, in coal measures, in the argillaceous schist, sandstones and magnesian limestones, whence it is obtained by sublimation, but it frequently appears in globules in the gangue stones, or in the crevices of rocks. In Peru is a mine 170 fathoms in circumference and 480 deep. In the womb of this dismal abyss are thousands of the human race immolated to avarice, who are plunged in naked and never more see the day light, their wretched existence being shortly terminated by convulsions and other maladies incident to those who are too much employed with this metal. The mines of Idria, Spain, and China yield immense quantities. In Sweden, Hungary, and the Palatinate, it is found combined with 36 per cent. of silver. However it mostly occurs as a sulphuret, which whether native or artificial is called *Cinnabar*, 84·5 met. 14·75 sul. The *hepatic* contains a little silex, alumine, and oxide of iron. *Horn* quicksilver consists of 76 oxide, 16·4 muriatic acid, and 7·9 sulphuric acid.

18. ARSENIC.

75 Metal,	25 Oxygen	.	White, or arsenous acid
67 Do.	33 Do.	.	--- arsenic acid

Specific Gravity 5·7.

ARSENIC is a bluish white metal, not unlike polished steel, brilliant, but soon oxides when exposed to the air and becomes almost black, yet remains unaltered in water or alcohol. In all its compounds it is highly poisonous. It has no smell while cold, but when heated or struck emits a very strong odour resembling that of garlic. It volatilizes at about 356 degrees in a white vapour, which when collected, crystallizes in cubes. It is extremely brittle, yet the softest of all the metals, and has a granular fracture. If inflamed and then put in oxygen gas, it will continue burning very brilliantly, but inflames spontaneously in chlorine gas, and combines with iodine.

Arsenous acid is sold in the form of a white powder, vulgarly called *White Mercury*; and is the deadly ingredient with which as a poison, the horrid crime of murder has been so often perpetrated. The best antidote, when it has been swallowed, is said to be a few scruples of *liver of sulphur*, (sulphate of potas), dissolved in a little more than half a pint of water, and given by little and little as the patient can bear it. The presence of arsenic may in any of its forms be detected, if in solution, by adding thereto a little of the above dissolved liver of sulphur, when it will be precipitated in the form of yellow orpiment. But if the arsenic be in any solid substance, then, should a little be placed upon a hot coal, or dropped into a clear fire, the metal will rise in white fumes with the smell of garlic.

Arsenic is used in the composition of specula for reflecting telescopes. Copper alloyed with it is rendered white, and the componnd is malleable, flexible, and susceptible of a very high polish. Many articles are made of this alloy which are washed or plated with silver. Arsenic renders lead brittle, and when fused and poured through a sieve, more apt to separate into grains. In this way is small shot manufactured; for being dropt from the top of a very high tower into water at the bottom, it is, by the attraction of aggregation, globulated on leaving the sieve, and in this form cooled or solidified in its descent. Arsenic is also used in purifying flint glass, as well

as for staining glass: the white twisted threads seen in the stalks of some wine glasses, are formed with it. *Butter* of arsenic is composed of 2 metal and 3 chlorine. *Scheele's green* is arsenic and potash. *King's yellow* is made from yellow orpiment. Sulphuret of arsenic is much used in calico printing, for de-oxydizing indigo, and rendering it soluble in alkali. Different shades are given to fine furs by solutions of this metal. The Chinese and other Eastern nations are said to form realgar into medicinal cups, and use lemon juice that has stood sometime in them as a cathartic; and one sixteenth part of a grain of white arsenic may be taken with the greatest safety as a remedy for inveterate agues.

MINERALS. Arsenic is rather an abundant metal, but chiefly belongs to primary districts; it occurs native along with the ores of several other metals, in many parts of Europe, and also, though sparingly, in North and South America. The white oxide occurs in many places, chiefly stalactitic. *Sulphurets* are found in Cornwall, Devonshire, at Alva Stirlingshire, and in various parts of the Continent. *Realgar* or native *red orpiment* is composed of 69 arsenic and 31 sulphur: it is of a scarlet or dark orange colour. *Yellow orpiment* 62 arsenic and 38 sulphur is of a beautiful lemon colour, and is generally found in secondary mountains. Pharmacolite or arsenic bloom, consists of 50·54 arsenic acid, 25 lime, and 24·46 water. Arsenic contaminates many of the British metallic ores; in Saxony it is generally separated from the cobaltic ores, by roasting them in furnaces, which have long horizontal chimneys. It volatilizes, and the vapour entering these flues, is therein condensed and encrusted, whence it is, at stated periods, withdrawn by condemned criminals, who would otherwise meet a more speedy doom.

19. MOLYBDENUM.

100 Metal	17 Oxygen	. Brown oxide	
	34 Do.	. Blue -	or molybdous acid, a fine blue powder.
	51 Do.	. White -	or molybdic acid, a pale yellowish pow.

Specific Gravity 8·6.

THIS metal is of a white silvery colour, verybrittle, and, when fused over charcoal with a stream of oxygen gas, burns with a white vapour, which when collected is in small needle formed

crystals. It is not a scarce metal, but it has not been brought into use, though it forms alloys with many of the other metals.

MINERALS. It has only been obtained in small grains from a mineral called molybdena, 60 metal and 40 sulphur, in outward appearance like plumbago—occuring in veins traversing granite, in Cornwall, near Caldbeck Cumberland, and Shap Westmorland; and in chlorite slate Inverness-shire. It also occurs in several parts of Europe, as well as in America. An oxide combined with iron occurs in Scotland and Norway.

20. TUNGSTEN OR SCHEELIN.

100 Metal	16·6 Oxygen	Brown
	25· Do.	Yellow, tungstic acid, which by exposure to light becomes blue.

Specific Gravity 17·4.

TUNGSTEN is a hard, brittle, granular, brilliant metal, of a colour resembling steel. It requires a very intense heat to fuse it, and is little inferior to gold in weight; the only use it seems to be put to, is, that of precipitating the colouring matter from certain woods for the purpose of forming the French *Lakes*.

MINERALS. It may be called a rare metal, is never found pure, and its ores, which are but three in number, are chiefly confined to the primary mountains generally accompanying those of tin or magnetic iron. *Wolfram*, 64 tungstic acid, 22 oxide of manganese, and 13·5 oxide of iron, is very common in Cornwall; it also occurs in Rona, one of the Hebrides, and in several of the continental mines. *Tungsten*, sometimes called Scheelium, from the chemist who discovered it, consists of 64 tungstic acid, 31 lime, 4 silica; and occurs in Cornwall, Sweden, Saxony, and Bohemia. An oxide is found in North America.

21. CHROME OR CHROMIUM.

100 Metal	Oxygen	Brown
	43·36 Do.	Green, chromous acid
	87·72 Do.	Deep scarlet, chromic acid

Specific Gravity 5·9.

CHROMIUM is a white, brittle metal, susceptible of a good polish, which remains unaltered by exposure to the air; requires a most intense heat to fuse it, does not readily burn, resists all

the acids except aqua-regia, and has slight magnetic properties. It derives its name from its imparting different colours to different substances. Its acid, combined with lead gives a beautiful orange yellow; with mercury, the colour of vermillion; with silver, carmine red; and with zinc or bismuth, bright yellow. It is but a recently discovered metal and its compounds are little known.

MINERALS.—Chromate of iron, 43 chromic acid, 34·7 oxide of iron, 20·3 alumine, 2 silex, occurs in Serpentine, in some of the Shetland isles, in Banffshire, in France, in the Uralian mountains, and in several places in America. *Chromate* of lead, 36·04 chromic acid, 63·96 oxide of lead, which is sometimes accompanied by a variety containing oxide of copper, occurs in the gold mine of Beresof, Siberia. Chrom-iron 2 per cent. of chrome has been found in the sands of the Rhine—accompanied by iron-stone, mica, and argentiferous gold. In the isle of Unst (Shetland) the oxide occurs along with the chromate of iron, which there abounds. Chrome gives colour to the emerald, the spinelle ruby, and some other earthy minerals. It has been detected in aerolites.

22. COLUMBIUM OR TANTALIUM.

100 Metal, 5·5 Oxygen . Oxide or acid.

Specific Gravity 5·61.

THIS is a dark-grey metal, but utterly infusible, so that the most perfect specimen consisted merely of hard grains closely agglutinated together. It may be reduced to powder, but even in that state resists the attack of all the mineral acids. If heated to redness, it takes fire and consumes slowly without flame. Little more is known of it, than that it differs in many respects from all other metallic substances. It combines with iron, and the alloy has the appearance of brittle cast iron; also with tungsten, forming a compound similar to pure tungsten, but is harder and takes a finer polish. It is a very rare metal.

MINERALS.—It was first discovered in a mineral, received from America, by Sir Hans Sloane, called by him Columbium, and deposited in the British Museum. Another ore was found in Finland called *tantalite*, and the metal from it was called *tantalium*, which proved on examination to be identical with columbium. The former mineral consists of 80 oxide of col.

15 oxide of iron, 5 oxide of manganese: the latter 83·2 oxide of tan., 7·2 oxide of iron, 7·4 oxide of manganese, 0·6 tin. Two varieties of the latter have been found in Germany. See Ittrium.

23. PLATINA OR PLATINUM.

93·5 Metal { 6·5 Oxygen . Black oxide
{ 13· Do. . Grey

Specific Gravity from 21 to 23.

PLATINA is accounted one of the precious metals. Its colour is between tin-white and iron-grey; it is capable of being very finely polished, but is not so brilliant as silver. It has nearly the hardness of pure iron, and like that metal may be welded. It possesses great malleability, tenacity, and ductility; is utterly infusible in the furnace, but submits to the burning lens and oxygen gas. When a piece is held in the flame of the blow-pipe, it burns with great rapidity, throwing off a profusion of brilliant sparks; yet it will not burn in chlorine gas, but rapidly imbibes chlorine, and is thus readily converted into a muriate. It resists the energy of all the acids except nitro-muriatic, but is corroded by the caustic alkalies; is unalterable by air or water, but may be oxidized by frequent shocks of electricity. It is utterly void of taste or smell, is the densest of all known substances, but conducts heat slower than any other of the metals.

Although this metal possesses most of the valuable properties of the other metals, its use has hitherto been confined to only a few purposes; such as mirrors for reflecting telescopes, utensils for the chemists, orifices for gas lamps, and touch-holes for fowling-pieces. It may be drawn into wire of little more than the twenty-thousandth part of an inch diameter, with heavy rollers may be pressed into sheets of almost any thinness, and has been beaten into leaves and applied to porcelain in the manner of leaf-gold. Yet one inconvenience attends it, which is, that it can only be soldered with gold. It forms many useful alloys, especially with copper, which metal may also be coated with platina almost as easily as iron with tin. The oxide is used for certain articles in pottery, and also in enamel painting. When this metal is heated to redness, and then introduced into a closed tube containing the fumes of phospho-

rus, the action is so violent that the platina becomes vividly ignited, and an infusible bluish grey powder is produced, consisting of 21·21 of phosphorus, and 100 platina: it may also be made to take a larger doze of phosphorus. It combines with sulphur in three proportions, viz. 19·04, 28·56, and 38 sulphur to 100 platina. For its combination with hydrogen see page 216.

MINERALS. Platina is a rare metal and always occurs native. In the district of Choco, Peru, it is found among the alluvial ores of gold in roundish flattened grains, not larger than a grain of sand; yet, in some instances, they have been met with as large as peas; one specimen, in the possession of the king of Prussia, is larger than a pigeon's egg, and there is another in the Royal Museum of Madrid whose longer diameter is 2⅓ inches and the shorter 2 inches. It also occurs near Carthagena, and in the gold mines of Brazil: the ore contains no less than nine different substances, viz. silica, iron, lead, copper platina, iridium, osmium, rhodium, and palladium. It is met with in St. Domingo, in the sands of a river called Jaki, at the foot of the Sibaen mountains on the east side of the island. The grains are here along with the ores of magnetic iron, gold, and other substances, and are larger than those of South America. This metal also abounds in the grey silver ores of Guadalcanal, Estramadura, Old Spain.

24. GOLD.

96·13 Metal,	3·87 Oxygen	.	Green oxide
89·225 Do.	10·775 Do.	.	Brown

Specific Gravity 19·3

GOLD has a fine, bright yellow colour, rather inclining to red, with a lustre scarcely exceeded by any of the metals. In hardness it is superior to tin, but inferior to silver. It exceeds all the metals in ductility and malleability, but its tenacity is less than that of iron, copper, platina, or silver, and it does not possess much elasticity. It has neither taste nor smell. It melts at 1,300 degrees, and then assumes a bright green colour inclining to blue. In this state, no exposure to the most intense heat, air, or water, for any length of time, will either diminish the weight or alter the appearance; and when permitted to cool it contracts in bulk, forming crystals in the

shape of quadrilateral pyramids. But although this metal is invincible when opposed to fire, air, water, and the common acids, it is conquered when attacked by the galvanic battery, the blow-pipe, chlorine gas and aqua-regia. The former two reduce it to a purple oxide, and the latter two to a muriate. Yet in the former state along with ammonia it forms fulminating gold, a most dangerous and destructive composition, and in the latter, when concentrated by evaporation it forms yellow crystals as beautiful as topazes; or if combined with ether, makes *potable* gold, which was once believed to cure every disease incident to the human race, provided only, the patient could procure a sufficient quantity of this royal metal in an unconquered state.

There seems to be some doubt respecting the oxides of gold, for besides the above, the purple and yellow are spoken of; yet, so little affinity has it for oxygen, that the mere rays of the sun will de-oxygenize it, and restore it to its pure state. Amalgamated with quicksilver, or alloyed with some of the other metals, gold by a slight heat may be easily calcined or oxidized, but a strong heat restores it to itself in its true splendor: hence the simile, that a *good* man entangled in the love and favour of the world, and suffering slight afflictions, is cast down and disheartened; but, should great afflictions come upon him, he breaks from his entanglement, despises the vain glory or censure of the world, and comes forth like gold seven times purified in the fire.

The chief use of gold is in its alloys, and that with copper is the most serviceable, because enough of this metal may be added to improve the hardness without doing injury to the colour. Standard gold of Great Britain, called 22 carats fine, is 22 of pure gold with 2 of copper. The current coin has generally a mixture of silver. One pound of sterling gold is always coined into 44½ guineas. Jeweller's gold is generally alloyed with copper, the pale with silver, and an alloy of gold and silver is used for soldering gold.

The colour and the weight of gold are the general criterions whereby to judge of its purity, though the latter fails when it is alloyed with platina. In this case the adulteration cannot be detected without dissolving the whole in aqua-regia, and then adding thereto a little dissolved muriate of ammonia, when the platina will instantly appear in a red precipitate. Gold in solution may be detected by the green sulphate of iron,

which makes a brown precipitate that soon changes to the colour of gold.

Gold may be drawn into wire of extreme smallness, and beat into leaves that may be blown away by the slightest motion of the air, even so thin that it would take almost 300,000 to an inch. An ounce of pure gold will gild a silver wire more than 1,300 miles in length, and the silver be so completely covered as not to be discernible by the microscope. The film must be so thin, that it has been calculated 14 millions of them would only make an inch in thickness, while the thickness of the same number of leaves of writing paper would be nearly three quarters of a mile. Yet a mixture of lead or antimony, though only a nineteen-hundredth part of the gold, would entirely destroy its ductility.

When leaf-gold is thrown into chlorine gas, at a temperature of 70 or 80 degrees, it burns with brilliancy. This muriate or the solution in aqua-regia is used for giving a fine purple red to ornamental feathers, to ivory, marble, and pottery, and in all cases is permanent. Leaf gold ground in honey is used by miniature painters. Gold unites with sulphur, and indeed sulphuret of potas will dissolve it. It is supposed by those who would explain the miracles recorded in Holy Writ, on natural principles, that this is the composition in which Moses rendered brittle the *Golden Calf* worshipped by the Israelites. (Exodus Chap. XXXII. ver. 20). Gold has been exposed to the very intense heat of a glass furnace for 30 weeks together, without injury of texture, or brilliancy, or loss of weight.

MINERALS.—To mention all the places where gold has been found, would be to enumerate all the primary districts of the world, and the alluvial and diluvial deposits in their vicinity. It always occurs in the native state, but generally alloyed with some other metal, as silver, copper, antimony, tellurium, platina, and arsenic. The island of Borneo contains the most productive mines in the world. The annual produce of America is stated at 30,000 pounds weight, most of which is from the alluvial grounds, or beds of rivers of South America. Yet it is found in many veins; and it is remarkable that rich veins of copper often terminate in poor veins of gold, which generally ruins the proprietors. They have a saying in South America that "a man gets rich with a copper mine, but becomes a beggar with a gold mine." Earthquakes often lay naked veins or lumps of gold. Part of a projecting precipice in one of the

highest mountains in Paraguay, fell down some 30 or 40 years ago, and pieces of gold from 2 to 50 pounds each were found in it. Grains of native gold have been found in Ireland, some pieces weighing 2 or three ounces, one was found that weighed 5 ounces and another 22 ounces. In Scotland it is said to have been found near the Lead-hills, also in Glen Turret, Perthshire. It has been found in Regent-mine, North Moulton, Devonshire, and in several of the Stream works of Cornwall. Notwithstanding all the new mines of gold, and the continual addition to the old stock, the monarchs of antiquity seem to have had greater abundance of this precious metal than these of the present day. For, Solomon, as it appears from, "The First Book of Kings" must have received 27 tons weight in one year. Should it be asked, "what has become of it?" Perhaps the most plausible answer that can be given, would be to suppose that almost every individual now possesses less or more, but at that time it was only in the possession of royalty.

25. SILVER,

100 Metal, 7·3 Oxygen . Brown. Specific Gravity 10·474.

SILVER is of a white colour, the most brilliant of all the metals, indeed nothing exceeds its splendor except highly polished steel. It is void of taste or smell, moderately hard, sonorous, very tenacious, malleable and ductile, is fusible at 1000 deg., and in cooling crystallizes in quadrilateral pyramids. It is combustible by the heat of a large lens, or the blow-pipe, and then burns very rapidly with a pale green flame. Silver wire may also be deflagrated with the galvanic battery, when it exhibits a very splendid appearance, and may be volatilized with a stream of oxygen gas. It very slowly tarnishes by exposure to the air, unless the fumes of sulphur are present, for which this metal has a very great affinity, though its peculiar affinity seems to be for muriatic acid. It also combines with iodine. Silver is said to be about 46 times more abundant than gold. The annual produce of both, in South America, is worth about 9½ millions.

Silver may be beaten into leaves so thin that 50 square inches shall not weigh more than a grain, and drawn into wire only half the thickness of a small human hair. For all its uses in ornamental works, domestic utensils, and current coin, it is

alloyed with a little copper to give it a greater degree of hardness and durability. The standard is 37 pure silver to 3 copper, and one pound of it is coined into 62 shillings. An amalgam is used for *washing* utensils of copper, &c.: it is much inferior to *plating*, The chloride of silver consists of about 75½ metal and 24½ chlorine, it is used in fulminating compositions. The sulphur contains 100 metal, 49·59 sulphur: it is similar to lead in texture, is of a violet colour, and useful as a test in some analyses. The phosphuret contains 20 per cent. of phosphorus, and is a white crystalline substance. But of all the salts of silver, the *nitrate* is the most useful. It is prepared by dissolving silver in aqua-fortis. When melted and run into moulds it is called *lunar caustic.* It is the most powerful antiseptic known. One ounce dissolved in 12,000 ounces of water will preserve it pure for ever; and it may at any time be separated, by adding thereto a little table salt. When dissolved in water, and suffered to rest, it crystallizes in differently shaped transparent plates. And though the solution in water is as clear as pure water, it will stain the skin and other animal substances with an indelible, black colour. Mixed with gum water it forms ink used to mark linen: the linen being first moistened with a solution of alkali, and then dried before the ink is put on. It is also used to dye human hair, to stain marbles and jaspers, and for silvering ornamental works.

MINERALS. Silver occurs native, also alloyed with antimony, iron, arsenic, lead, copper, bismuth, gold, and some others: likewise combined with chlorine, sulphur, and the carbonic and sulphuric acids. It is principally met with in primary rocks, but not those of the oldest formation, there are also veins containing it in secondary rocks, but it never occurs in alluvial deposits. It is found in various parts of the world, but the Andes furnish about nine or ten times as much as all other places. It is calculated that in the three last centuries, between three and four hundred million pounds troy have come from these mountains, which in bulk would make a solid globe of about 91 feet diameter. In Peru at an elevation of three miles above the sea is a mass of porous brown iron stone half a mile in length, and breadth, and above 100 feet in depth, interspersed throughout with pure silver, and containing a white argillaceous vein of great richness. The surrounding district has yielded forty millions of dollars in one year. But New Spain is now said to yield the most: a mine at Valencia is

1640 feet in depth, and 8 miles in horizontal extent, employs 3,100 persons; yields £500,000, and leaves a profit of £200,000. In Cornwall, native silver has only been found in clay-slate, and principally in the north and south veins. The other ores of silver have been found in nearly all the mining districts, and in almost all parts of the world. All the lead mines yield it. The lead procured from a mine in the county of Antrim, Ireland, contains a thirtieth part of its weight; the lead mines of Cardiganshire were once very productive. The presence of silver may be ascertained, by reducing the ore to powder, and then dissolving it in nitric acid, to which add a little muriatic acid, and it will precipitate the silver in white flakes, which after being heated to redness, will contain three fourths of its weight of the pure metal.

26. PALLADIUM.

87·55 Metal, 12·44 Oxygen . Chesnut-brown oxide.

Specific Gravity 11 or 12.

PALLADIUM is a white metal, similar to platina; it is very hard, and capable of being polished, malleable, but has little elasticity or ductility, and when broken exhibits a crystalline texture. It is not altered by exposure to the air, soluble only in aqua-regia, and produces a beautiful red solution, fuses with difficulty, but burns very brilliantly when submitted to the intense heat of the blow-pipe. It is a rare metal, being only found in very small quantities combined with platina; though a distinct ore has been found in the gold and platina districts of Brazil, consisting of palladium, platina, and iridium, but the first greatly predominates.

27. RHODIUM.

100 Metal	6·71 Oxygen	Black
	13·42 Do.	Light Brown
	20·13 Do.	Dark Red

Specific Gravity 10·649.

RHODIUM is a white metal with a yellowish tint, not unlike silver. It is as hard as iron, but much more brittle, is one of the most infusible metals, insoluble in the acids, forms alloys with

all the metals except mercury, almost all of which are soluble in aqua-regia. It readily combines with arsenic or sulphur, and in either case the compound is very fusible. Its salts give rose coloured solutions, from which the metal has its name. It only occurs combined in very small quantities with native platina.

28. IRIDIUM.

Deep Blue and Dark Red oxide: proportions not known.

Specific Gravity 18·68.

IRIDIUM is a white metal, in appearance similar to platina. It is brittle and so difficult of fusion, that a compact and solid mass has not yet been obtained. It is soluble in 300 times its weight of aqua-regia, forms alloys with several of the other metals and greatly increases their hardness. A large portion combines with gold without injury to its colour. Its salts in solution exhibit a variety of colours, from which this metal has its name. As the most perfect specimen hitherto obtained was porous, it has been supposed that if it could be completely fused and afterwards hammered, its specific gravity would exceed that of platina. It combines with sulphur in the proportion of 100 metal to 33·3 sulphur. It only occurs alloyed with osmium.

29. CADMIUM.

This metal was discovered in 1817 in an ore of zinc found in Silesia, but it has since been recognized in some of the English ores of that metal. It resembles tin in colour, lustre, softness, ductility, and in the sound it emits when bent, and melts, and volatilizes at a few degrees below the temperature required for that metal. Its specific gravity is 8·6.

CHAP. XIV.

The Electric Energies the Grand Movers of Nature.

1. Formation of the Heavenly Bodies. 2. Comets. 3. Theory of Gravitation and Planetary Motion. 4. Theory of Light and Heat. 5. The Sun. 6. Magnetism. 7. Electro-Magnetism.

1. FORMATION OF THE HEAVENLY BODIES.

In referring to Sir W. Herchel's observations on nabulæ at the conclusion of Chap. IV. we made mention of his opinion that there is in the universe "unformed matter of a luminous nature." He imagines this nebulous matter to be the elementary substances of the heavenly bodies in their most simple state, that is, *gaseous*; and by their chemical affinity to be combining, concentrating, and assuming the cometary, and finally the planetary or stellar form. That which is the least condensed he calls *diffused nebulosity;* the next step, he terms *nebula;* then, *globular* nebula; *cometary* nebula; *planetary*; and lastly, *stellar* nebula. But each of these divisions includes a number of nebulæ; so that, they graduate into each other.

Diffused nebulosities exist in great abundance. In one, the nebulosity extends over 150 square degrees; so that, Herschel supposes we can, in some cases, set no limits to its extent; and that its quantity exceeds all imagination. In general, it has a milky, white appearance; but in some places its light is so very faint, that the telescope is unable to ascertain its limits. All the diffused nebulosities have places in them of a much greater

degree of brightness, wherein it is supposed the nebulous matter is much more condensed. Where these condensed places are very conspicuous, they take the name of "Nebulæ, having nebulosity joined to them."

Nebulæ are often brighter in two or more different places. In the great nebula of Orion, all varieties, both of the brightest and faintest nebulosities are to be seen, and that with a moderately good telescope. Some nebulæ have three or four bright nuclei, and these he thinks, in the progress of condensation, will separate into so many distinct bodies of nebulous matter. In support of this opinion, he has observed double nebulæ, whose situation with respect to each other, induce the belief that they have been formed from one nebulosity. The present state of the heavens presents us with several collections of scattered nebulæ, plainly indicating by very remarkable arrangements, that they owe their origin to some former common stóck of nebulous matter.

Whatever be the figure of the nebula, the brightness increases from the circumference to the centre. But the more they are condensed, the rounder is their central appearance; so that, the most condensed always present a *globular* form. In one instance the nebula appears like a long narrow oval, with a dark line along the middle. He supposes it to be in the form of a ring, whose edge, like that of Saturn, is nearly towards us.

Among the many nebulæ he has seen, there are several which have the appearance of telescopic *comets*. These seem to be in a higher state of condensation than the globular. They have a bright centre, then a dark interval, and around this a bright *coma*. Some of these are still more concentrated; so that, their brightness exhibits an abrupt brightness, which may be supposed to be the nucleus; and the coma is in some become almost invisible.

Planetary nebulæ are those wherein the nuclei have assumed something of a planetary aspect; but yet are surrounded with a haziness, that shews their nebulous origin. It is not supposed that the matter is really solidified in these, but that it is in a fluid state. They generally have somewhat of the elliptical appearance, supposed to be occasioned by a rotatory motion, in which they assume the oblate spheroidal shape. Perhaps the most remarkable of these, is, "A beautiful, bright, round nebula, having a pretty well defined planetary disc of about 10 or 12 seconds in diameter. It is a little elliptical, and has a

very small star following, which gives us the idea of a small star accompanying its planet. It is visible in a common Finder (telescope) as a small star." In common good telescopes, planetary nebulæ cannot be distinguished from stars.

The *Stellar* nebulæ differ from the planetary by being more uniformly or more intensely bright, and are generally smaller than the planetary; some of them he supposes to be the planetary in a higher condensation. They are almost as small as stars, but are evidently not stars, having some nebulous accompanyment, such as a very faint coma, a stream on one side like part of a coma, surrounded with a bur, or in other respects differing from a star, as being larger and fainter, of irregular figure, or of irregular brightness. One has a faint star with a coma and two burs; and there are two others nearly like it; and, lastly, some are so completely formed, that it is doubtful whether they are nebulæ or real stars.

Some stars have been called nebulous which are not in reality such;—but their light passing through nebulous matter, causes them to have a hazy appearance, as when we view a planet or a star of the first magnitude through a hazy atmosphere. This is ascertained from some stars in Orion, which were once nebulous but are now no longer so. The great nebula in that constellation, having since the first observations were made upon it, considerably contracted the limits of its nebulosity, so that it is now no longer between us and those stars. And from the appearance of other stars, it is supposed that nebulous matter exists in the universe which does not emit light; or, is not in a state of combination.

The above process of concentration is perfectly consistent with the new doctrine of the Electric Energies; and tends to establish the theory built upon their being the Grand Instruments by which nature is put in motion. We hence infer that the matter, which composes the spheres of the Solar System, was once in a chaotic state, or was a nebulosity similar to those now floating in the regions of space. While in this condition the elements were in an uncombined state, each with its full charge of its respective electric fluid; and they would therefore exist as so many gases. Darkness would pervade the whole. For we can imagine a space in Eternity between the first creation of matter, and the commencement of the combination of the two fluids; and as light is a production of such combination, consequently, this would be the reign of *perpetual night.* For

any thing we know to the contrary, many parts of the Universe may contain unlimited portions of dark and therefore invisible matter.

A second step in this process of Nature would be when the two fluids began to combine, the ponderable bases of the metals condensing first into compound gases or aeriforms; then, liquids; and afterwards solids, during which the whole would be luminous. Such are now the nebulous masses we have been describing, and which may be considered as incipient worlds. And in this manner might a nebulosity or a chaotical part of the universe, reaching on all sides to half the distance between the sun and the nearest fixed stars, be combined into the bodies which compose our Solar System.

But, *thirdly*, while a mass of matter was thus passing from the chaotic or nebulous state to the globular, it would assume the cometary form; that is, being affected by no attraction but that existing among its own particles, its elementary substances would gravitate towards the centre which would become a nucleus, and around this to a great extent would be aeriform elements, more condensed than in the simple nebulosity, but prevented from immediate combination, or rushing as it were at once into a solid mass, by the caloric liberated from the combination, and solidifying of the nucleus. Another circumstance would have a more material effect in rendering the process of concentration very slow;—on account of the immense distance of some parts of the nebulosity from the nebula or central part of attraction, the action on it would be less than any assignable quantity; and though great changes of figure have taken place in some of the nebulosities since observations were first made upon them; yet, taken as a whole, these changes are but trifling;—in this case, says Herchel, "millions of years may be but moments". However this process would continue till the whole of the substances were combined, their ponderable bases still gravitating or passing through the vapour, and increasing the bulk of the nucleus. The last process would be, when the whole cooled, the aqueous vapour would condense into water; and the earth and other planets would then pass into a habitable state.

Nevertheless we are not to suppose that all this took place under no other direction than that of blind chance. Let us trace Nature as far up towards the source as we choose, we come no nearer to a knowledge of the DEITY, nor discover less

occasion for His creative power; and however we may develope the laws of her operations, and shew their immutability, we still see a need of the same Almighty Power to uphold, and of the same directing hand of Infinite Wisdom to guide the whole.

2 COMETS.

But we are not confined to the supposition that the whole of the planetary bodies, which compose our solar system, were formed from one nebulosity. The sun with two or three of them; or the sun alone, might be the whole of one primitive concentration, and the other or all the primary planets and their secondaries might be, successively, new accessions, viz. extinguished comets, which, being attracted to within a certain distance of the sun, are made to revolve round him.

"From the complete resemblance of many comets," says Herchel "to a number of nebeulæ I have seen, I think it not unlikely that the matter they contain is originally nebulous. It may therefore possibly happen that some of the nebulæ, in which this matter is in a state of high concentration, may be drawn to the nearest celestial body of the nature of our sun, and after the first perihelion passage round it, proceed in a parabolic direction towards some other similar body, and passing successively from one to another, may come into the regions of our sun where at last we perceive them transformed into comets. The brilliant appearance of our small comet (speaking of the comet of 1811), may therefore be ascribed, either to its having lately emerged from a nebulous state, or to having carried off some nebulous matter situated in the far extended branch of its parabolic motion. The first of these cases will lead us to conceive how planetary bodies may begin to have existence, and the second how they may increase and afterwards grow up to maturity. For if the accession of fresh nebulous matter can be admitted to happen once, what hinders us from believing a repetition of it probable? And in the case of parabolic motions, the passage of a comet through immense regions of such matter is unavoidable". See Phil. Trans., v. 95.

The detail, which we gave of the process of concentration in the above section, corresponds with the observations of Herchel upon the comet of 1811. The globular nucleus or planetary body, forming a centre to the whole, was visible by its own

light, which was of a pale ruddy tint. The head or nebulous matter surrounding the nucleus, was nearly globular. The nucleus was not at the centre, there being the greatest extent towards the sun. Its light was of a greenish or bluish-green colour, and its intensity was the greatest towards the centre or around the nucleus. An atmosphere, not self-luminous, but so transparent that stars were visible through it, surrounded the head. A luminous envelope or coma surmounted the atmosphere. Its shape was partly circular, but in its course it did not extend quite half round the head of the comet. A little before it came so far, it divided itself into two streams: one passing by each side of the head, and extending in the direction of the tail, seemed to inclose it on each side. Its light had a strong yellow cast. The colour of the tail, which was by far the most brilliant part of the phenomenon, was a bright white, and perfectly resembled the milky part of the nebulosity of the nebula in Orion. (For dimensions, see page 14)

Now supposing the whole comet to consist of nearly the same elementary substances that compose the earth, some aeriform, some fluid, and the rest solid, but most of them in a state of combustion or ignition, that is, combining and concentrating. In treating of the simple substances, we have shewn, that each during combustion emits light of a colour peculiar to itself; we cannot therefore expect that the light of the comet will be of a uniform colour. The nucleus will consist of substances the most condensed, viz. of the metals or of their oxides about to solidify into rocks. These being in a state of ignition will emit a red light; and if the whole be in a state of fluidity, as it most probably is, will nevertheless assume the globular form, which observation proved this part to have. The head of the comet will be the place wherein the gaseous acids will arrange themselves, which, uniting with the metals, or the metalloids that keep the aeriform state at a less temperature, may produce that greenish or bluish green light which this part emits. Around these acids or aeriform metalloids, is ranged the oxygen gas or a mixture of gases similar to that of our atmosphere;—its lower part combining with the more weighty aeriforms, as the metalloids, and forming oxides or earths that gravitate towards the nucleus, forming the rocky substances; and its upper part surmounted by the lightest gases as the carburetted, the phosphuretted, and lastly, the pure hydrogen.

When at the greatest visible distance, comets seem to have a globular form; but advancing towards the sun, they begin to shoot out a long stream of light called the tail, which increases in length till they arrive at the perihelion, when it attains its maximum, After they have passed the perihelion, it begins to contract, till, (as was the case with that of 1811,) before they finally disappear they regain their globular form. The predominating electricity of the solar atmosphere we suppose to be the positive; and bodies during combustion emit with the flame or vapour the positive fluid, the negative remaining with the uncombined or combining materials. The hydrogen gas of the cometary envelope, which is a positive element, will also in this case be positively charged; therefore, as the comet approaches the sun, the hydrogen gas will be repelled in the direction of the tail, which is always projected, whether the comet is advancing or receding, in a direct line from the sun.

As to the two streams spoken of, they are merely optical deceptions, occasioned by the envelope being in the form of a hollow hemisphere. We shall therefore in the middle see but its depth, which is only about 68 thousand miles; while, looking through it past each side of the atmosphere, it will be not less than four times that thickness, and hence will give us the appearance of two streams. Plumes of light were also observed to shoot periodically from some parts of the envelope; hence it was supposed that the comet had a rotatory motion on its own axis.

The light of the nucleus or head of the comet we attribute to ignition and combustion; and that of the envelope or coma, and of the tail, as also a great part of that of diffused nebulosity, we ascribe to the uncombined electric fluids, maintaining a constant *aurôra*. In a globular nebula the external part must consist of matter or gases in the highest conceivable tenuity, and this external part must be as highly charged with the positive fluid as it is capable; while the central part or head must be equally charged with the negative; the positive will therefore gradually attract the negative, and combining in the envelope or coma, they will maintain a constant light as explained in a following chapter under the article *aurora borealis*. When the nebula takes the wandering state, and approaches the sun, this external gaseous and highly charged body is repelled in the

formation of the tail, but the combination of the two fluids is not interrupted. But as the tail consists of gases of the greatest tenuity, while those forming the envelope towards the sun are more dense, this may account for the light in the former case being white, while it is yellow in the latter.

As to the identity of comets, Herschel asserts that only one has been recognized in its return, though it is well known that at least 500 have been seen; but on our hypothesis many of these may be returns of the same, which must every time present a different appearance, and therefore it will be impossible to recognize them. Now the first time a comet approaches the sun, the combustion will be the greatest, its matter being the least condensed, it will then be the most luminous, and have the most extensive tail. The comet of 1811 was probably in this state; or, its perihelion passage in that year may be considered as the first. Should this comet visit our solar system a second time, its nebulous part will be considerably diminished, and the nucleus enlarged, the combustion will be much less intense, the light less vivid, the head smaller, and the tail considerably shorter.

Such we may conceive to be the state of the comet of 1812, the tail of which was only 659 thousand miles in length, although the diameter of the nucleus greatly exceeded that of the above comet. After another perihelion passage, the combustion of the comet of 1812 may therefore be expected to cease: it will have attained the planetary state, and will be also constrained to the planetary orbit. Indeed, of this comet Herschel observes, that "had it not been for an extremely faint light in the direction opposite the sun, it would hardly have been entitled to the name of a comet."

But he conceives that a comet in its wanderings may come in contact with, or pass through nebulous matter, and by this means may obtain new accessions to its envelope, and thus its energies and combustion will be renewed. He also conjectures that comets may gravitate round two or more suns, and if so, then we have no certainty of a comet that has once visited our system ever returning, since it may pass into the planetary state and attach itself to some other sun, and become a member of its system, ere it finds its way back to ours. Hence the planetary bodies, which compose our Solar System, including the earth itself, may have been comets that have here ceased from their aberrations.

3. THEORY OF GRAVITATION AND PLANETARY MOTION.

We consider the Heavenly Bodies as vast electrics, not that they are substances merely charged with electricity, but that every atom of each of them has its complement of inherent or combined electric fluid, and that it is the aggregate of these fluids in each mass, which gives them their respective motions.

It is not intended in this theory to impugn the Newtonian philosophy of gravitation, but rather to attempt an explanation of a cause whose effects it so satisfactorily demonstrates. Electro-chemistry being in the days of Sir I. Newton unknown, he could have nothing but conjectures respecting the cause of gravitation, and it is wonderful how exactly in conformity with this doctrine his conjectures are.* He, towards the close of life, was not averse to the idea that gravitation might be carried on by the intervention of a subtile fluid, which for want of a better term, he called *Ether*. This subtile fluid we affirm to be *Electricity*. But whether there is an intervention of these fluids or they exert an influence at a distance, which seems more probable,† we may require, as Paley conjectures, a sixth sense to enable us to understand; and must class it along with the doctrine of *Spiritual Influence*, which it seems to resemble in more particulars than that of its being beyond the limits of the perceptive powers of our present five senses.

There seems to be an internal motion among all the celestial bodies. Our system is demonstrated to be proceeding towards

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* "It is to the same great genius, (says Sir H. Davy), who developed the laws that regulate the motions of the heavenly bodies, that chemistry owes the first distinct philosophical elucidation of the power, which produces the changes and apparent transmutation of the substances belonging to the earth. Sugar dissolves in water, alkalies unite with acids, metals dissolve in acids. Is not this, says Newton, on account of an ATTRACTION between their particles? Copper dissolved in aqua-fortis is thrown down by iron. Is not this because the particles of iron have a stronger attraction for the particles of the acid than those of the copper; and do not different bodies attract each other with different degrees of force?"

† We are inclined to support the opinion that gravitation exists without any intervention of fluid; since two charged or electrified bodies exert an influence on each other at a distance without any diminution of their charges; and magnetic bodies lose none of their strength or intensity by use.

the constellation of Hercules. Whether this is a kind of planetary motion, wherein each solar system acts a subordinate part of one grand system in the universe, or a revolutionary motion of the whole cluster of the Milky-Way, or it is the general effect of a predominant gravitation, and all these luminaries are rushing into a heap, we cannot possibly determine. It is enough for our present purpose that gravitation is universal. With respect to our system we believe the sun to be the centre of attraction; that both the sun and planets are composed of negative and positive materials, and perhaps in equal proportions; that there is a determinate quantity of each electric fluid inherent in each individual body, which mutually act as the band of the globular mass; that the negative and positive of the sun attract the positive and negative of the planets, which is the *centripetal force;* and that the *centrifugal force,* is, the repulsion existing between the homogeneous fluids in each body.

"Sir I. Newton found, that when a convex lens was put upon a flat glass, it remained at the distance of the $\frac{1}{137}$th part of an inch; that a very considerable pressure was required to diminish this distance, and that no force which can be applied will bring them into actual mathematical contact. Other philosophers have shewn, that the particles of no body whatever are in such contact; that in every case there is a distance between them, consequently that the particles of all bodies repel each other. According to Boscovich, the atoms of which all bodies are composed, are mere mathematical points destitute of extension and magnitude, but capable of acting upon each other with a force, which differs in intensity and in kind, according to the distance. At sensible distances the force is *attractive,* and diminishes inversely as the square of the distance. At the smallest distances the force is *repulsive;* it increases as the distance diminishes; and at last becomes infinite or insuperable, so that absolute contact, of course, is impossible." (Parkes' Chemical Catechism, 8th Ed., page 440.)

Now to apply the above to gravitation or the descent of falling bodies. Suppose a small stone elevated to a certain distance above the earth's surface, it will descend to the earth (we suppose the earth stationary) in the direction of the centre of gravity. And suppose a free passage to the earth's centre, the stone would not descend to the central point of gravity, but would be repelled or suspended at a certain distance from it. Suppose a larger stone elevated to an indefinite distance, the earth's

attraction and its own attraction for the earth would bring it from a greater distance than the former would be brought from, but in its approach to the earth's centre, it would not go so near the central point of gravity as the former, because as its quantity of matter is greater, and its attraction extended to a greater distance, so its repulsion would take place at a greater distance where it would be suspended. We might next suppose a body so large, that the point whereat the attraction and repulsion balance each other, shall be at the earth's surface. One a little larger would remain at a distance from the surface, or would revolve round the earth; our next step might be the moon; or, removing the central point of gravity from the earth to the sun, we then have planetary motion.

The action and reaction of the sun and a comet are exactly the same as that existing between two mere particles of matter. They *attract* each other when at a certain distance, but when within that distance they as violently *repel*. When a comet is at the farthest end of its elliptical orbit, it is attracted by the sun; and this attraction is such, that the comet acquires a momentum or *projectile force* that carries it so far within that point at which the attraction and repulsion are balanced, that the action of repulsion becomes much greater than the action of attraction as acting at one time ever was. At the moment therefore when the comet is nearest the sun, being driven by its acquired momentum, and repelled by the sun's repulsion, its matter becomes compressed by a much greater force than that of its own attraction of aggregation. Hence a perihelion passage may be considered as a concentration, which must cause a great increase in the emission of caloric, and, of course, of the two electric fluids: therefore, comets at the perihelion invariably exhibit a very sudden, and a very large increase of splendor. It should be remarked, that comets, being supposed originally at rest as globular nebulæ, will by reason of their coming from a greater distance than at any succeeding time, acquire the greatest velocity at the first perihelion passage. They will not recede from the sun to their original distance, and will have less velocity in the second perihelion passage, consequently will not approach so near to the sun: their eccentricity diminishing every time, till they have no more than the general eccentricity of the planets. Some comets are supposed to have their orbits entirely within that of Uranus; and indeed there is reason to believe that at least two of the asteroids, viz.

Ceres and Pallas, were but recently comets, since, not only are their orbits very eccentric, but both of them are surrounded with a little nebulosity. It has been said that there is a comet, or perhaps it might be called a fifth asteroid, that has its aphelion point within the orbit of Jupiter. Its period is only $3\frac{1}{4}$ years, and it is supposed to have been seen in the years 1786, 1795, 1801, 1805, and 1818.

Now, though we have all along considered the electric fluids the cause of attraction; yet, we by no means consider them as distinct from matter, or, as if matter by being divested of its electric fluids lost weight or gravitating power, for in fact the contrary seems to be the case. A magnetised bar of steel is observed to lose somewhat of its weight, the same has been observed with respect to electrified bodies, and a common aerolite will glide a long way across the earth's surface while it retains its heat, but as it cools it descends towards the earth, explodes, and precipitates a shower of stones. The most dense bodies (platina always excepted) have the greatest attraction for heat. Now the most dense bodies are generally such as have parted with the greatest number of definite proportions of the electric fluids; and as the attraction of gravitation of the earth is the same as that of caloric, so it will exert a greater influence on these exhausted particles than on the other; though the difference on account of the small quantity that man can operate on may not be ascertainable. On this principle we arrive at very important results with respect to astronomy, viz. that the distances of the planets from the sun, will not be altogether according to the bulk and quantity of matter contained in them, but according to *that* and their want of concentration, or the fewness of the definite proportions of the electric fluids which they have parted with. The planets at the greatest distance from the sun may, therefore, have the least density, a conclusion nearly the same as that arrived at by philosophers on very different principles.*

* The principle on which the density of the sun and planets, as stated Chap. IV., was found, is, as follows. The moon is moved round the earth with a certain velocity, and retained in her orbit by the earth's attraction. The same must be the case with the other primary planets and their satellites. The nearest of Jupiter's satellites is about the same distance from him that our moon is from the earth. If the mass of Jupiter's satellite equalled that of the moon, and moved with the same velocity, it would be concluded that Jupiter

Now Mercury's greater density will be owing to his having been formed of a nebula, at a much greater distance from the sun than any other of the planets of our system. Consequently, coming from a greater distance than any of them, his momentum would be the greatest; he would at his perihelion passage approach much nearer the sun, and would suffer a proportionately much higher concentration. He would therefore longer continue his cometary eccentricity; and, of course, be subject to more concentrations than the other planets. And supposing the sun not to be the only body formed from the primitive nebulosity, but that one or more of the planets were formed at the same time;—The known proportional density will lead us to determine which of these planets were thus formed; or rather, which of them was the nearest nebula to that of which the sun was formed. Several circumstances point out Saturn as the one that was the nearest, and consequently suffered the least concentration from perihelion passages: he has not only the least density of any of the bodies of our system, but his double ring and belts indicate a deficiency of concentration at the time of his formation.

This theory of gravitation and planetary motion is the same

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and the earth possess the force of attraction in the same degree. Now the bulk of Jupiter is 1400 times that of the earth, and therefore, were his density equal to the earth's density, and the moon and satellite equal, the motion of the satellite should be 1400 times swifter than that of the moon: whereas it is only 16 times. They calculated therefore that the specific gravity of Jupiter is about 4 times less than that of the earth. And pursuing the calculation with the known density of the earth, with respect to the sun and primary planets, they have obtained the following results: taking water as the standard or 1 the specific gravity of the Sun is $1\frac{1}{8}$. Mercury $9\frac{1}{6}$. Venus $5\frac{4}{5}$. Earth $4\frac{1}{2}$. Mars $3\frac{2}{7}$. Asteroids nearly 2. Jupiter $1\frac{1}{24}$. Saturn $\frac{3}{8}$. Uranus 1.

The density of the earth was found by the deflection of a plumb-line caused by the attraction of the mountain Schehallien in Scotland. Having selected a fixed star in the zenith, they suspended a piece of lead as near the precipice as convenient, which, by the attraction of the mountain mass, was deflected to a certain degree from the perpendicular. They tried with the same star in the zenith on the opposite side, (the fixed star having no parallax it would be in the zenith on each side,) and obtained a similar result. Now the mountain is composed of granite, whose specific gravity is about $2\frac{1}{2}$; so that, they determined that of the earth to be about $4\frac{1}{2}$ as above stated. But later and repeated trials gave a result of somewhat above 5, as the earth's specific gravity; so that, the sun and each of the planets will have a density proportionately greater than stated above.

if we extend it to primary planets and their satellites; viz, that according to the quantity of matter, and their respective densities will be their distances from each other. Hence, though the bodies of our sytem, should be a little dragged from their stations; yet, they would, when that disturbing force ceased, regain their present orbits. And should a comet approach us, we need, perhaps, be under no apprehension of its striking the earth, or of its annoying us with its tail. It might affect the earth's motion or probably make some alteration in the bed of the ocean, but such would be its projectile force or the momentum given it by the sun, that the earth would hardly arrest its progress, and attach it to itself as a satellite; nor could it run away with the earth as a satellite, since, were its bulk large enough, it would by the sun be kept at a sufficient distance beyond the earth's orbit. The comet of 1811 would contain considerably less matter than the moon, yet with its great momentum, it did not approach nearer the sun than 97 millions of miles, that of 1812 did not advance nearer than 164 millions; while that of 1680, which seems to have had the greatest velocity of any on record, was at its perihelion not more than 130,000 miles from the solar surface. Dr. Halley supposed its greatest distance to be not less than 13,000 millions of miles.

However it is possible to suppose that the matter in a comet may be so small as to be attracted to the earth, but it would only be in the form of a fiery meteor, and meteors and meteoric stones, or aerolites have been accounted for in a much less probable manner. Should a comet be of such magnitude as to have its balancing point of attraction and repulsion at a short distance from the earth's surface, it would pass the earth as a fiery meteor, some of which Sir H. Davy supposes to encircle the earth in very eccentric orbits. (See meteors and fire balls. Chap. XVI). That some comets contain very little matter is evident, from its being related that one in 1454 eclipsed the moon; and another in 1770 passed either very near or through the satellites of Jupiter; yet, in neither case was there any confusion produced in the motion of the neighbouring planets. And Sir W. Herchel mentions five, as seen by his sister, which were mere luminous vapours.

The nature of planetary motion is such as to place it beyond the possibility of proof by direct experiment. The following experiments, which are detailed in the "Encyclopedia Perthensis," under "Electricity," may, perhaps, somewhat illus-

trate it. On the knob of a prime conductor, suspend six or seven concentric metallic hoops of different sizes, as nearly as convenient to correspond with the orbits of the different planets. Beneath these hoops and at the distance of about half an inch, place a metallic plate, upon which and within each hoop, place finely blown glass bubbles to represent the planets. Then charge the conductor, and the bubbles will begin to revolve round the hoops. Should the charge be strong, the bubbles will sometimes leap from the hoops, and they will then be seen to revolve on their own axes. Should the experiment be performed in the dark, the bubbles will be luminous. The experiment, which we select as being illustrative of the motion of the secondary planets, seems more to the purpose. Take a cork ball and cut it into two hemispheres, then scoop out each like a bowl, and join them together again with a little paste. Suspend this hollow ball by a silken thread of about three or four feet in length and let it touch the knob of a prime conductor. Then charge the knob and the ball will leap off. But should a candle be placed a little way from the ball, so as to form a line with it and the knob, the ball will begin to move at a distance round the knob, not in a circle, but in an irregular ellipsis similar to the lunar orbit. To these experiments may be added some of those hit upon by Mr. Faraday and Sir H. Davy in Electro-magnetism, which prove, that the electric energies in two bodies freely suspended or as near as may be under such circumstances as the sun and planets, will cause them to revolve round each other. (See sec. 7).

4. THEORY OF LIGHT AND HEAT.

There are two theories of the origin and nature of light and heat, supported by philosophers of the present day: the *one*, that they consist of two distinct kinds of particles accompanying each other from the sun, or separating from bodies during combustion; the *other*, that they are mere motion communicated to matter. Perhaps the true theory may embrace the union of both. But till we have some mode of language, by which we can render the nature and transmission of the electric fluids more tangible by the understanding, and shew how attraction acts at a distance, without, as far as we at present know, any material medium; also develope the lays of crystallization or the polarization of matter; we may, perhaps, despair of seeing a

theory of light and heat, that will, in all parts bear the test of a rigid demonstration.

Heat. All matter is essentially combined with the two electric fluids, which form the band that holds the original particles of all bodies together. Now the greater the quantity of caloric given out by the chemical combination of the elementary substances in any body, or, the more the electric principle is detached from the original particles, the more closely they unite, and the greater is the specific gravity of that body. It is also found, that the greater the density of any body, the more rapidly does it imbibe heat; that is, the less of the electric fluids inherent in it, the greater attraction has it for them in the calorific combination. Again: whatever the density of a substance may be, it is always diminished by the presence of heat and increased by its absence. Suppose a substance entirely deprived of caloric, or to contain no portion of the electric fluids except what is inherent in the original particles; then, that substance would be at its ultimatum of specific gravity, or greatest diminution of bulk; at the utmost limits of cold, or would then possess the greatest attraction for heat. Now every new accession of heat increases its bulk; and, therefore, its particles must recede from each other, till they lose their mutual attraction and become repulsive: for solids are first converted into fluids, and afterwards become aeriform or gaseous. Hence it appears, that the elementary particles take in their full complement of their respective electric fluids, and that caloric produces its effects on matter by first combining with the original particles, and then subjecting them to certain laws. For it seems, the two opposite fluids, when they approach at and above a certain degree of concentration, do not remain at rest, but commence a peculiar motion; and that, even when they are combined with or are inherent in their own elementary substances above a certain proportion, they possess the same tendency to motion, notwithstanding this load, as when alone. The original particles of every substance, therefore, under the influence of caloric being evidently in motion, this motion must be, in the words of Sir H. Davy, "a vibratory or undulatory motion, or a motion of the particles round their own axis, or a motion of particles round each other."

"It is possible to account for the phenomena of heat," he farther observes "if it is supposed that in solids the particles are in a constant state of vibratory motion, the particles of the

hottest bodies moving with the greatest velocity, and through the greatest space; that in fluids and elastic fluids, besides the vibratory motion, which must be conceived greatest in the last, the particles have a motion round their own axis with different velocities, the particles of elastic fluids moving with the greatest quickness; and that in ethereal substances the particles move round on their own axis, and separate from each other penetrating in right lines through space."

Light. Light and heat both proceed from the combination of the two electric fluids; and the intensity of light is always proportionate to that of heat; so that, the light produced from the galvanic apparatus, and by a stream of oxygen gas upon a piece of ignited charcoal, which are considered the greatest concentrations of heat, is too vivid for the eye to look upon. Also if four lamps be placed so near that their flames unite in one blaze, they will emit as much light as six would do burning with separate flames; the heat by their flames uniting being so much the more intense.

We have already shown Chap. VIII. s. 4. that the solar rays, and it is the same with the rays from all combustion, when made to pass through a prism are refracted and decomposed. The lowest or least refracted rays produce heat, but no light or colour; and in the middle are the rays of colour, which, being blended together, are the rays of light, but which form heat also; and that beyond the rays of colour, are rays called the de-oxygenyzing rays. Sir W. Herschel ascertained by thermometers placed in the different rays, that the rise of temperature in each class is, as follows: the calorific rays 9, the red 7, the green 5, and the violet 2.

Sir I. Newton supposed these effects might be produced by a difference in the size of the molecules of light; and later philosophers have discovered, that the rays at the violet side of the spectrum produce, to a certain degree, all the same effects as negative electricity; and, on the contrary, those on the calorific side, the same as the positive fluid. The new or white muriate of silver is rendered black in all the rays of colour, but this is effected by the violet in fifteen minutes, whereas the red rays requires twenty minutes, to produce the same effect; and in the rays beyond the red its whiteness is partly restored. Phosphorus is inflamed by the red, and extinguished by the violet; the yellow colour of guaiacum is changed to green in the red, and its proper colour is restored by the violet; and in-

flammability is produced in vegetables by the rays at the red side of the spectrum, but no colour; and colour is produced in them by the rays of the violet side, but no inflammability.

All solid substances, especially such as are crystallized, have a peculiar arrangement of their original particles, occasioned by the polarities of their integrant molecules as they solidify, (see page 306). The rays of light, therefore, in passing through such substances must be variously affected. When they pervade the atmosphere and water, which are not solidified, or not under the influence of the attraction of cohesion, they are merely refracted. But when a ray traverses certain crystallized substances, as a rhomboid of calcareous spar, or a series of parallel plates of glass, it becomes divided into two points, or rays, and the light is then said to be polarized.

One of these rays is according to the ordinary refraction, as when it passes through water, having a relation to the angle of incidence; but the other is according to the axis of crystallization. If the incidental ray is parallel or perpendicular to this axis, there is but the one ordinary ray; but should they form any angle except the right angle, the ray of extraordinary refraction is exhibited at an angle with the other ray greater or less according to the angle formed by the incidental ray and axis of polarization.

When light is thus polarized by passing through a double refracting rhomboid of calcareous spar, and the rays are caught by a second rhomboid, whose axis of crystallization is parallel to that of the first, they pass on without molestation; but if the axes are not parallel, each ray is again separated into two. The utmost limits of this, is, when the second crystal is turned so far round, that the axes make an angle of 45 degrees; but should it be turned till the angle is 90 degrees, then, the two rays continue; only, that which was ordinarily refracted by the first is extraordinarily refracted by the second, and vice versâ the same with the other.

Polarization may also be effected from reflecting surfaces:—different substances requiring different angles of the incidental ray: that of glass is 35 deg. Again if a ray of polarized light is made to pass through a thin leaf of mica or selenite, and be decomposed by a rhomboid of double refracting spar, the two rays will reflect two images of different colours, which being again blended, produce the common white light. The rays on

entering the mica, penetrate entire to a certain depth; but at different depths according to the different coloured particles, they begin to have the appearance of oscillating like the balance of a watch. And the velocity of these oscillations is the least among the red particles, and commences at the greatest depth; and is the greatest among the violet, and commences at the least depth. Hence it appears that the rays at the violet side of the spectrum, are more impeded in passing through certain media, than those at the red side.

Though white light consists of a mixture of all the colours; yet, taken separately, there is more light in those of the red side of the spectrum, than in those of the violet; however the yellow rays afford the most, that is, a book may be read at a greater distance with the light of the yellow rays, than with that of any of the rest. But the red rays are the strongest or most penetrating; for in media that can be the most dimly seen through, the light always appears red.

Theory.—Since we find light and heat proceeding in direct lines through space, and having internally highly repulsive properties, also giving motion to particles and rendering them highly repulsive; and as the sun and planets have no other motion than what is occasioned by their electric energies, may we not suppose that the unmolested, direct and internal motion of light and heat is identical with that of planetary motion? The sun with all his attendants is proceeding in a direct line towards the constellation of Hercules, in like manner the rays of light and heat always penetrate in direct lines through space. The planets are stationed at certain distances from the sun and from each other, within which distance, we suppose the centrifugal force would be much increased; now, at the place or focus where light and heat are concentrated or generated, may we not suppose that the molecules are under the same condition as the sun and comets or planets at the perihelion, and that the repulsion or the effect of caloric, as stated in the second paragraph of this section, is a mere struggle of the centrifugal force? With Newton we therefore suppose the solar rays to consist of molecules differing in size, the largest or suns penetrating in direct lines through space and revolving on their own axes, having therefore a direct and rotatory motion; while the smaller or planets revolve round them, and also on their own axes, having a rotatory and revolutionary motion. But that the molecules of light and heat produce their effects by communi-

cating motion to matter, is evident from this; viz. electricity produces no light when discharged *in vacuo*. And of course, since there is nothing to receive the caloric, it produces none of its effects, and therefore we may say, it produces neither light nor heat. In this we combine the two theories; viz. light and heat consist of two distinct kinds of particles emanating from the sun or bodies during combustion; but these particles produce their effect by communicating motion to matter.

Among the corroborating circumstances of this hypothesis, is, the appearance of a polarized ray when made to pass through a leaf of mica, which seems to diminish the velocity so much as to enable us to detect the nature of the internal motion. The violet rays appear to oscillate like the satellites of Jupiter when viewed through a telescope of small power, or as the bodies of our solar system would appear to do, if they were viewed by a spectator placed at a certain distance beyond the orbit of Uranus. Besides, as both the sun and planets revolve on their own axes, the calorific rays, as may be judged from the appearance of the red in the mica, revolve much less rapidly than the violet, bearing the same proportion that the sun does to the planets: for none of the planets are much above 24 hours in performing one revolution while the sun is 610 hours.

The larger particles or suns we therefore consider as the calorific rays, the smaller revolving round them or planets the cause of light and colour, but alone they produce only chemical effects. Now in passing through the prism the solar beam is partially decomposed, the planets to a certain degree are separated from the suns; so that, the suns alone are the calorific rays below the red, and their temperature is 9. We shall say then that the calorific rays contain 9 suns and no planets. The temperature of the red is 7, or, the red rays contain 7 suns with some planets: that of the green is 5, or, the green rays contain 5 suns and more planets; and that of the violet 2, or two suns with a greater proportion of planets; while the rays beyond the violet produce no ascertainable increase of temperature and therefore are planets with few or no suns. But the calorific rays produce effects similar to those of positive electricity, while the deoxygenizing rays are like to those of the negative. From this we infer that each sun is surrounded by an atmosphere of positive electricity, and each planet by one of the negative fluid, and in this respect also they resemble the heavenly bodies. From these premises may possibly be deduced all the pheno-

mena of light and heat, except refraction and polarization, which, depending on the polarities of the original molecules of matter as stated Chap. XII. s. 15, cannot in the present state of the science be developed.

The suns are therefore the largest, and are what move in a direct line taking the planets along with them, and being positive they penetrate those substances wherein the negative fluid is predominant more readily than the other; that is they permeate glass, and are reflected by the metals; hence all earthy substances especially those of a black or dark colour attain a much higher temperature when exposed to the solar rays, than combustible or white substances; and in transparent substances the more the positive elements prevail the greater the power of refraction, so that Newton concluded the diamond to be a combustible from its great refrangibility. Bright and polished metals, that is, such as contain no oxygen on their surface and reflect the rays parallel, are the principal reflectors of light, and it is supposed by philosophers, that reflected light never touches the reflecting surface, but is repelled when at a certain distance, in the same manner as a comet with all its momentum never reaches the solar surface. Diamond differs in one respect from all other combustibles, for they all become negatively electrified by friction, but diamond whether polished or rough always becomes positive. May not therefore the uncommon splendor of the diamond, in some measure, depend upon this peculiarity, viz. it permits the positive suns to enter, but being a combustible the negative planets gain admission also;—the molecules of light are therefore concentrated in the diamond, but by reason of the positive fluid being predominant in its original particles, the suns do not become latent or enter into the calorific combination, but, after the diamond is saturated, are repelled as from a focus with an increase of velocity? Hence this gem appears as a blaze of light. A diamond while exposed to the full rays of the sun, was covered up with black wax, and when opened some years afterwards in the dark, emitted light.

Charcoal contains very little oxygen as to its mass, but attracting oxygen rapidly into its pores, it presents a perfectly oxygenized surface. Now the oxygen on the surface of charcoal is not chemically combined, and, therefore, it contains its full complement of inherent electric fluid. Recently dyed substances generally become much darker coloured by exposure to the air, when, like charcoal, they imbibe oxygen. Also when

a piece of polished steel is slightly heated on one edge, the extremities of the increase of temperature, after being cooled and exposed to the air, exhibit the prismatic colours, the violet being next the heated edge, which, on account of its temperature, imbibed the most oxygen. Such substances may therefore permit the suns to enter, when the planets, being negative, are repelled. Now as oxygen exists on the surfaces of substances, as on charcoal and some substances dyed black, with all its electric energies: and in the composition of other substances, having parted with various proportions of its electric fluid, the solar rays on entering such substances must be decomposed in an infinite variety of ways some being absorbed and others reflected:—hence the origin of colours. But from combustible substances purified from this adventitious oxygen, they are nearly all reflected: if the surface be polished, it is *bright* from the rays being reflected parallel: if rough, as the fracture of metals or the surface of white paper, it is merely *white*, from the reflected rays, (not being parallel), confusedly crossing each other.

Charcoal will admit all the suns, so that the revolutionary motions of the planets will cease, or if reflected to the eye they will make a faint impression, wanting suns to give them energy. Distilled water effects the rays of light partly in the same manner as Diamond; but sea water, on account of the salt which it contains, reflects the rays from the middle of the spectrum or the bluish green. The atmosphere, except when clouds intervene, is on the same principle as the diamond; the rays are concentrated in it, being negative the suns are enabled to penetrate it, taking their planets along with them, whose revolutionary velocities are accelerated by the repulsion of the negative medium. But the colour of the atmosphere itself is blue. In dense media, as solids, that contain much oxygen, the calorific rays penetrate alone, hence there is sometimes much heat but no light emitted, and if they possess a very small degree of translucency, the light viewed through them always appears red, these being the strongest or containing the most suns. The reverse of this ought to take place in very small apertures in metallic substances; these should permit light to pass and not the largest of the suns or calorific rays: hence, perhaps, the efficacy of Sir H. Davy's Safety Lamp.

The different effects produced by the molecules of light and heat may therefore be thus stated. Those of heat combine with

the original particles of matter and give them their repulsive energy: hence they possess a decomposing property causing the particles to have a vibratory and lastly a progressive motion. The molecules of light produce their effects by being near to the suns which give them motion, consequently light and heat are proportionate; for the more suns the more heat there must be and the nearer also must they be to each other, and consequently the greater will be the velocity of the planets. Hence friction or compressure, by bringing the latent caloric within the repulsive limits must resuscitate its repulsive properties and put it in motion or produce heat. But, though we have thus endeavoured to develope the cause of light; yet, its effects must be principally sought for in the impression made on the organs of sight; (for which see Chap. XX.)

5. THE SUN.

SIR Isaac Newton supposed the sun to be a globe of fire, but Sir W. Herschel ascertained it to consist of a dark opaque body with a luminous atmosphere. In this atmosphere are suspended two strata of clouds; that next the sun being more compact than the other, and not self-luminous; the other one luminous, very irregular, uncompact, or corrugated, and permitting us everywhere to see through its corrugations. He supposes the utmost limits of the atmosphere or of the luminous stratum to be not less than 1843, nor more than 2765 miles high or distant from the solar surface; and that the inner stratum is of a planetary nature, and serves to shield the body of the sun from the direct rays of the self luminous stratum. Taking the direct rays transmitted from the luminous stratum to the earth at 1000, he calculates that the inner stratum, where we are permitted to view it through an opening of the outer, reflects 469 rays to the earth; and that the dark body of the sun, when viewed through an opening of both strata, reflects only from 7 to 16; so that these black spots, as they are called, are not uniformly dark.

He imagined the light to be caused by the combustion of a gaseous substance similar to that with which we illuminate the streets, and that a continuous supply of this gas is emitted from the solar mass. Hence a solution of what has very much puzzled philosophers, viz. the black spots on the sun's disc. For though there may be a continual perspiration of this gaseous

matter; yet, it is often locally impeded, and then obtains vent in large masses or eruptions bursting through both strata of clouds; and, being transparent thus permits us to have a glimpse of the sun's opaque body. As may be expected, he says, that hurricanes or violent atmospheric commotions are visible around these openings and closings of the solar clouds. It is observed in general of these spots, that as they disappear the sun's disc becomes more luminous on that part than any where else; and Herschel says, that the sun emits more light and heat the more black spots; and goes back a century or more to prove from the spots on record, that there were, when the sun continued free from them for any length of time, years of scarcity.

All this is perfectly in harmony with electro-chemistry; but we object to the supposition of the sun's atmosphere being in a state of combustion. By combustion is meant, not only the union of the two electric fluids, but the condensation of elementary substances, as the ponderous bases of the combining gases. The idea would indeed be beautiful enough, were we to adopt the fanciful hypothesis of the balmy dews that might be thus distilled. For as he supposes the gas to be similar to that with which we illuminate the streets, viz. carburetted hydrogen, and of course combining with oxygen, it must produce a proportionate quantity of water and carbonic acid gas. Now as this is the true food of the vegetable kingdom, it would answer the exact purpose of our rains and the manuring of our lands. And suppose the lower part of the atmosphere to be oxygen gas without our quadruple portion of azote, then this abundance of the ascending inflammable gas, and of the vapour and carbonic acid gas continually generated in the uppermost regions of the atmosphere, and gravitating towards the solar surface, might bear only the same proportion to the vital air, that the other component gases of our atmosphere bear to our oxygen; and consequently, a being, equipped with such a pair of lungs and vital apparatus as the inhabitants of the earth are furnished with, might, perhaps, do very well in the solar abodes.

However, we have a much more simple method of accounting for the light and heat emitted from the sun, or generated by his beams. The two strata of clouds seem to argue that the sun partakes somewhat of the cometary state, or more properly, is a globular nebula. We have already supposed the sun to have been originally a nebula; and that he should still retain some of its nebulosity, while the planets, with the slight excep-

tion of the aurora borealis, and perhaps the belts of Saturn and Jupiter, are entirely destitute of it, may be owing to the following circumstances. The comets, as we have shewn, are concentrated at each perihelion passage; and by a repetition of these, they lay aside their nebulosity, and assume the opacity of the planets. But the sun remains stationary in the place, or nearly so, of his original nebulosity: his mass was never compressed by a perihelion passage round a body as much larger than himself, as he is larger than a comet or any of the planets of our system. And, therefore, the component ingredients of the sun retain a great deal more of their inherent electric fluids than those of the planets; a necessary result of which, is, a much greater quantity of the uncombined fluids, which are continually charging his atmosphere and maintaining a continual combination in the external stratum of clouds.

We, therefore, suppose the light of the sun to be exactly of the same nature as that of our *aurora borealis;* viz. the upper regions of the atmosphere are charged with positive electricity, while the earth and lower regions are charged with the negative; and these, on certain occasions, meet together, combine and form the aurora. In the sun's atmosphere, in the envelope and tail of a comet or in the external parts of a nebula, is a constant aurora, and from that of the sun are distributed light and heat to the planets. Now it is not here supposed that the solar light and heat as found in the planets are altogether the result of an indiscriminate radiation, as from a candle, when the rays are distributed in all directions through the gaseous medium of the atmosphere, but that the particles are principally attracted by the planets, so that, where there is no attraction of a planet there is, perhaps, little or no radiation. Should this be the case, the solar light and heat in each planet will be according to both the mass of matter and the degree of concentration. If the mass of matter is great, the quantity of the solar rays will be proportionately great; if the matter is highly concentrated, as in the denser planets, Mercury, Venus and the earth, they will be proportionately greater than in the less concentrated planets; but, the atmosphere of the denser planets will be less than that of the rarer, and, therefore, the light will be less:—consequently, Saturn being the least concentrated will attract fewer particles, but having the most extensive atmosphere, these particles will produce the greatest effect, and therefore, instead of this planet's quantity of light and heat being only

a hundreth part that of the earth as stated Chap. IV. it may, in fact, be equal to it.

Should it be objected that the sun may become exhausted, we see no reason why it may not be supposed, that, as the sun is the centre of gravitation of our system, hither may be attracted all the redundant caloric of the system, so that a circulation between the sun and planets and in short all the heavenly bodies may be in continual operation.

On this hypothesis the black spots on the solar disc are accounted for nearly in the same manner as on Herschel's; only, substituting the electric for the gaseous fluid. For though it is found that the negative fluid is almost continually perspired from the earth; yet, sometimes it is impeded, till at length it is so highly condensed as to break forth in one shock, which, as we shall shew, is the cause of earthquakes and hurricanes. In like manner are discharges from the sun's body, which will sufficiently account for the almost instantaneous openings of the solar clouds, shewing to us the opaque orb, or producing black spots. The motion of the clouds around these spots is sometimes so rapid as not to be accounted for on any other principle. And as the discharges from the earth are the most frequent in mountainous regions, so may we also suppose that the like events generally happen on the solar mountains. On the same principle, also, when the spots have disappeared, will their places be the most luminous, not so much on account of the vast quantity of the electric fluid discharged in the shock, as, because the whole charge is not emitted at once, or, from this conductor a regular stream is continued for some time, which is not too great for the combination, as was the case with the main discharge, and therefore this place may be more luminous than the rest of the disc: hence, as Herschel endeavoured to prove, the quantity of solar light and heat may be proportionate to the black spots.

The irregularities of the sun's surface, with respect to liberating or conducting the electricity, may perhaps account for the corrugated appearance of the luminous stratum; but it should be remembered, that whenever the uncombined electric fluids unite, they always do it in shocks: hence the flashes of lightning and also the darts and streamers in the aurora borealis: but we have only an internal or else a profile view of the aurora—while we have a full external view of the solar surface.

The following experiment may, perhaps, be considered as

illustrative of the subject of this section. In an exhausted glass receiver, suspend two finely polished metallic balls by two wires, so, that the balls may be at the distance of a few inches; and charge them by the wires, the one negative and the other positive. The balls will then appear surrounded with atmospheres, and the hemispheres opposite to each other will be unequally luminous, that of the positive ball having the most light. It is found impossible to exhaust a receiver entirely, and therefore these atmospheres may be considered as the remaining particles of air thus arranging themselves around the electrified surfaces: hence we infer, that owing to the sun's external stratum of clouds being positively charged, a negative charge is excited in the surface of the earth and lower parts of the atmosphere, which is an auxiliary to the solar light and heat; and we also infer that it is the superabundance of the electric fluids in the planets, whether as caloric or as inherent electric fluids for want of concentration, that causes them to be surrounded with atmospheres.

6. MAGNETISM.

THIS has lately become a favourite science among a large class of the first rate experimental philosophers. It is divided into two parts, viz. *Magnetism* and *Electro-Magnetism*:—the former treats of the action of magnetised bodies, and endeavours to ascertain the laws of that action;—the latter is occupied in developing the intimacy between the electric and magnetic fluids;—this part of the science is only in its infancy, but it promises most important results, such as will eventually connect magnetism with the other subjects of this chapter.

The *Natural Magnet* or *Loadstone*, is an ore of iron and was described page 316. The whole of the ore is capable of being attracted, but there are interspersed in it, smaller masses which possess the power of attracting the whole mass as well as each other; the former has therefore been called *passively* magnetic, while the latter, which is the true *magnet*, is said to be *actively* magnetic. Each one of these masses, then, is a magnet; but into how many pieces soever it may be broken, each fragment possesses exactly the same properties as the whole mass; that is, it has two opposite points, called its poles, possessing opposite properties. One of these poles is capable of being repulsed by a charge of the negative electricity, and attracted by the

positive, while the other, is attracted by the negative electric fluid, and repulsed by the positive :—each magnet, therefore, possesses a negative and positive pole. Also the negative poles of all magnets repel each other, but attract the positive; and, on the contrary, the positive are repulsive of themselves, but attract the negative, in the same manner as bodies charged with the electric fluids. But there is this difference; when two electrified bodies come in contact by their mutual attraction, the fluids are discharged, and the bodies (no longer possessing attraction) separate: while magnetised bodies remain clinging to each other. Also, it is observable, that the magnetic powers are not impeded by intervening bodies, provided they are not magnetic; but the electric powers of attraction and repulsion do not act through non-conducting substances.

When a magnet is attached to a piece of cork that swims freely in water, or is suspended by a thread fastened to its middle, or is delicately balanced on a pivot, so that it may turn round with the least possible friction, the negative pole arranges itself nearly towards the north pole of the earth, and the positive, of course, in the opposite direction. The negative pole is, therefore, called the North Pole, and the other the South Pole. But when a magnet has freedom of motion, it does not remain parallel with the horizon, but, chiefly in northern latitude, the north pole is depressed, or dips towards the earth, while the south pole is elevated: this depression or dip, at London, is now, 1825, about 70 deg. But in southern latitude the dip, as it respects the poles, is reversed. To account for this phenomenon, the earth is supposed to be a large magnet with its poles situated at opposite parts of the surface, towards which the poles of the small magnet are attracted; and as the north pole of one magnet is attracted by the sonth pole of another, it is supposed that the north magnetic pole of the earth possesses the same property as the south pole of the small magnet. Supposing, then, the earth's magnetic poles to be at opposite points of the surface, or so situated that a line passing through them would also pass through the earth's centre; a circle therefore, passing through each pole of the small magnet and continued all round the earth, would evidently pass through the earth's magnetic poles, or intersect the magnetic axis at two opposite points of the earth's surface :—such a circle will consequently represent the *magnetic meridian*.

In general, the smaller the magnet the greater in proportion is the power. A magnet worn in a ring by Sir I. Newton, though weighing only three grains, would lift 746 grains, or nearly 250 times its own weight; while one of two pounds or upwards, seldom lifts more than 10 times its own weight. The natural magnet or *loadstone* has likewise the power of calling forth the magnetic virtues in iron and nickel, till these metals, especially iron, are much more powerful than itself. Soft iron receives the magnetic properties much more readily than tempered steel, but as readily loses them; while hardened steel retains them, under proper management, for any length of time; so that, as steel is capable of being manufactured into any variety of form, while the natural magnet is not, magnetised steel is preferred for all useful purposes. Such is the attraction or repulsion of two powerful steel bars, that it requires the strength of an able bodied man to separate them when their north and south poles are joined, or to join their two north or two south poles.

But steel bars do not receive magnetism by the contact of the loadstone alone,—they will impart it by friction to each other; and it may be equally communicated to them by a smart stroke on one end with a hammer, by a shock of electricity, by the galvanic apparatus, by dipping one end in an acid, by being heated and cooled either in water or exposed to the air, by lightning, or by being a long time exposed to the weather, and the electricity of the earth and air; in short, it is communicated to them in all cases wherever the latent caloric of the iron is disturbed, by the excitation of electricity or the vicinity of a magnet, providing only, (except when the exciting cause is very powerful,) the bars be placed in the magnetic meridian or nearly perpendicular. Hence the poker is almost always magnetic, as also old bars of iron, such as window stanchions or iron railings. Likewise, if a magnetic bar, having its poles at right angles to, or reversed in the magnetic meridian, be treated in the above manner, its magnetism is destroyed. Though in the latter case, should the shock of electricity or exciting cause be very powerful, its poles are reversed, that is, the pole which was before the north, becomes the south; electricity will also fix the poles or change them according to the manner of its passing through the bars.

A piece of steel made so, as when suspended on a pivot, it may not be much impeded by friction caused by its weight, and highly magnetised, is called a *needle*. Almost every practi-

tioner has his peculiar mode of imparting the magnetic properties to steel bars which is often carried on with great secresy. With these bars the needles of the mariner's compasses are magnetised, and are frequently re-touched, so as to ascertain whether they have the powers sufficiently strong, or in the poles according to their marks, for the poles have sometimes been reversed by lightning. A great deal depends upon the temper of the metal: a needle, it seems, ought to be hard at each end, and soft in the middle, and the mode of tempering, recommended as the best, is, to harden the whole needle at a red heat, and then to soften the middle to within an inch of each extremity, by placing it across a piece of red hot iron, as a poker, till the blue colour has arisen and just disappeared.

A magnetic bar is rendered more powerful by being bent somewhat in the manner of a horse-shoe, but having its sides longer (or more nearly resembling an ass's shoe;) and the virtue is increased by keeping, provided a piece of iron or steel communicate with each pole; or, in case of two horse-shoe magnets being used, the north pole of the one communicate with the south pole of the other. When a straight magnetic bar is to be preserved, the iron or steel must be so bent as to communicate with each pole; or two pieces must he used, and joined so as to form a triangle with the magnetic bar. A magnet under such circumstances is said to be armed, and the pieces of iron or steel are called its armour or armature. When thus armed a bar is more powerful than when naked; and its power may be increased by *loading* in the following manner.—Take a small piece of iron, with a slight hook, to which attach a bag or scale; then suspend the iron by the attraction of the magnet, and at intervals of a day or so, keep loading the bag or scale, with a few grains of sand or small shot corns: then, the weight that breaks the connection is the power of the magnet. But if we wish the magnet to retain its greatest power, we must not break the connection by overloading; for, in this case, the power of the magnet will be nearly as when we began; otherwise, it may be made to support two or three times its weight.

The bodies, which we have hitherto described, are made permanently magnetic; that is, when approached by each other, they attract or repel according to the poles; but when bodies that are only passively magnetic are approached by either pole of a magnet, the opposite pole is immediately induced in that body without any motion of its mass; consequently, they are

always attracted. Soft iron, nickel, cobalt, chromium, zinc, and bismuth, as well as their ores, are of this description. Of all the metals arsenic seems the most hostile to attraction. Most earthy minerals, especially when they have been in the fire, are magnetic. The calcareous are the least so, and the silicious the most. The garnet with some others are magnetic. The transparent minerals, whether naturally so, or deprived of their colour by heat, do not exhibit magnetic properties. Amber, and almost all animal and vegetable substances after being burnt are magnetic. The earth itself is a large magnet, and therefore, many masses on its surface, as a house, a rock, or ship, are always under its influence, and have their poles according to their position. However, it is found, that in such bodies as are solid, the magnetic virtues only reside in the surface. A hollow globe of iron, provided the thickness of the shell be more than one-thirtieth part of an inch, is as powerful as a solid ball.

It is evident, therefore, that a body under such circumstances, can never possess a directive power, since however the mass is moved, the poles change place; and are always in the direction of the exciting cause. But when an active magnet or a permanently magnetised steel needle is suspended, so that it may possess freedom of motion, it will point towards the magnetic poles of the earth. The *Mariner's Compass* is such a needle suspended over a circular card. The true meridian serves as a diameter, and the two semicircles are generally numbered from the north to the south 180 degrees each way. The quadrants are therefore east and west, and the ends of the diameter or meridian represent the north and south poles of the earth. The needle being properly suspended arranges itself at about 24 deg. to the westward of the true north; and *this* is called the *variation* of the compass. From this it is evident that the magnetic poles are not at the true poles of the earth; and as the variation is counted from the true meridian, it must differ in quantity at almost every different place on the earth's surface:— the above is the variation at London.

But actively and passively magnetic bodies differ in another respect. In the former, the magnetic powers are concentrated at each pole; but in the latter, the poles seem indefinitely near each other at the centre of the whole magnetic attraction; so that, the magnetic axis of such masses is a mere geometrical line extending through these central points in each direction

till it pierces the surface. In irregular bodies, the magnetic poles will be at the centre of the surface, which may differ from the central point of gravity; but in spheres, such as iron balls, the centre of gravity and the magnetic centre are coincident. The earth is supposed to be a magnet of this description; and, consequently, the magnetic poles must be indefinitely near to each other at the earth's centre. This important fact was deduced by Mr. Barlow, from his experiments on iron balls, and is established by the observed dip of the needle in all parts of the earth, as well as by the intensity of the magnetic power. Had the magnetic poles been situated at the surface of the earth, and had the earth in other respects represented an active magnet, then, as navigators approached either pole, the intensity, which increases as the square of the distance diminishes, would have increased to an unlimited degree; whereas the contrary is the case, for instead of the needle becoming more active near the magnetic poles, it becomes so sluggish in its motions as to be nearly useless

Were the magnetic powers concentrated at two opposite points of the earth's surface, then, the needle would always point to these poles. At half way between them, being equally attracted by each, it would be parallel with the horizon, or there would be no dip: this would be the case all round the earth, so that it would form a great circle at right angles with the magnetic meridian, and would represent the *magnetic equator*. Northward of this circle, the north pole of the needle would dip towards the north magnetic pole, and this dip would increase till the needle arrived at the pole itself, where it would be perpendicular to the horizon: the same may be observed as it regards the south pole. As the magnetic poles are here supposed to be antipodes to each other, therefore, these poles, and the true poles of the earth would be situated under the same meridian. And as the magnetic variation is counted from any true meridian of the earth, it is evident that a compass on this meridian, would not only point to the magnetic poles, but also to the true poles of the earth: consequently, on this circle there could be no variation; and the nearer to this circle on any part of the earth, the less the variation; so that, a circle at right angles to it or a true meridian at half way between, would be the circle all round the earth, on which the variation would be the greatest. Also, the circle of no variation, must determine the name of the variation whether *east* or *west*. Had this

been the case, the dip and variation of the needle, would always have pointed out the latitude and longitude of the place in whatever part of the world.

But though the magnetic poles are placed indefinitely near to each other at the earth's centre, were the magnetism uniformly disposed around the earth's surface, and could the variation and dip be at all times accurately ascertained, the latitude and longitude of the place might still have been deduced by calculation. However, this is far from being the case: the earth's magnetic powers are supposed to be occasioned, either by internal fires, or by its beds of magnetic ores, here and there unequally distributed around the surface; so that, in some measure, every place, according to the presence of these mines of fire, or beds of iron ore, or their vicinity, seems to have a magnetic pole of its own: hence both the dip and the variation, as taken in different parts of the world, are very different from what would be the result of the above supposition. Yet numerous as these magnetic poles must be, all the north poles agree in pointing to somewhere within the arctic circle, near the middle of the arctic part of North America. Captain Parry, in his first voyage, supposed the magnetic pole to be at 73 N. Lat. and 102 W. Lon. But no other observations, either as to the poles or great circles of no dip and no variation, agree with this. In fact, observations differ in the place assigned to the pole, as much as 55 deg. Lon., and 10 deg. Lat.

As we have already stated, almost every body is rendered passively magnetic by the earth's attraction; and the poles in such bodies must be always in the line of the dipping needle, which forms a different angle with the horizon in every part of the earth's surface, except at the magnetic equator. For instance, if we suspend a ball of iron, it will be magnetic, the north pole will be near the lower side, and the south near the upper, so that a line passing through these points, will, at London, make an angle of about 70 degrees with the horizon. Such a ball, therefore, will be the earth in miniature; for if we make a circle round it at right angles to one passing through the poles, it will represent the magnetic equator. A needle placed any where with its pivot in the plane of this circle, will have each pole exactly at an equal distance from each pole of the ball; and therefore all round this plane the ball will appear as if it had no effect upon the needle; it is, therefore, called *the plane of no variation*. But in any place whatever out of this

plane, the needle will be deflected from the position given it by the earth, according to i s vicinity to either pole of the ball. If near the ball it will obey the magnetism of the ball; but at a certain distance the influence of the ball will only interfere with that of the earth. By experiments on balls and guns, Mr. Barlow deduced rules for determining the centre of attraction, and plane of no variation in the most irregular bodies.

Every ship, on account of the iron it contains, is passively magnetic, and has poles and a plane of no variation like those described in the ball; on this account the mariner's compass in ships can hardly be any where placed so as to be at full liberty to obey the magnetic influence of the earth. Indeed such is the quantity of iron in ships of war, that this instrument, of whose virtues we have been accustomed to hear such marvellous accounts, has nearly fallen into disuse: for it has sometimes obeyed the influence of the iron of the ship rather than that of the earth, turning everywhere along with the ship. However, the real cause of this defect was not suspected till within half a century ago; and only within a few years has it, from the repeated calamities occasioned thereby, received serious attention. The observations stated above with respect to determining the magnetic pole were made under its influence, hence perhaps a great part of their want of coincidence.

Mr. Barlow, though the principle had already been pointed out, was the first that set about correcting it in a practical manner. He commenced the process by experiments on balls, shells, and guns; and by the important discovery, that the magnetic poles of passively magnetic bodies are indefinitely near to each other at the centre of the whole of the magnetic surface,—he arrived at the happy conclusion that however an irregular body, such as a ship, may be turned, the centre of magnetic attraction will always be at the same place. Now as the power of attraction diminishes as the square of the distance increases, it is evident, that a small piece of iron placed near a compass will produce the same effect as a large mass placed at a greater distance,—he conceived the idea, therefore, of placing an iron ball so as to balance or neutralize the ship's effect on the needle, and thus leave it at liberty to obey the influence of the earth; but this he found would occasion the ball to be differently placed every time it was used. He therefore changed his plan, and placed the ball with its centre in the line joining the pivot of the needle and the centre of the ship's

attraction, so as to double the effect of the ship's attraction; and its position for producing this effect being once determined, the deviation in whatever part of the world, or whatever the position of the ship, providing no material alteration take place in the quantity and disposition of the iron, will be the same. And as he afterwards discovered that the influence of iron is not according to its mass, but to its surface, he introduced a thin plate of iron of about 12 or 14 inches diameter with a brass socket at its centre instead of the ball, as being more manageable. By this means he has restored the mariner's compass to its pristine honours; aud has, in some measure, met with that encouragement from his country that his merits deserve.

When a convenient place, on shipboard, for the azimuth compass, has been selected, the first thing is to ascertain the centre of attraction of the vessel, or the line joining it and the pivot of the needle. This is done by fixing a theodolite on shore by an azimuth compass, and then taking the same compass on shipboard,—an observer at the theodolite and another at the compass, take the bearing of each other by signal at the same moment. If there was no local attraction of the vessel, these bearings would be the same but in opposite directions; consequently, the difference is the local attraction of the vessel. However, should the centre of attraction of the vessel be in a line with the observers, either before or behind that in the ship, that is, should they all be in the magnetic meridian, then, there will be no deviation caused by the local attraction of the vessel: consequently, the more the central point is removed from the magnetic meridian passing through the pivot of the needle, the greater the deviation caused by the ship's attraction. The greatest effect will, therefore, be, when the central point is in the magnetic east or west: and the deviation will also be east or west according to the position of this point. Having, therefore, ascertained the deviation, for any one direction of the ship's head, the plate is fixed so as to double it. And, of course, however the ship is turned, so as to vary the deviation in quantity, that caused by the ship and plate will still be equal; so that if the azimuth be taken without the plate, and again with the plate, the difference is the quantity of local attraction. If the bearings, as taken without the plate, be diminished by the plate, then the local attraction is to be added to the angle of the first bearing; but if increased, it must be subtracted.

The power of the plate is ascertained on shore, by placing an

azimuth compass on a wooden pedestal. In a vertical line of this pedestal are bored 7 or 8 holes about an inch asunder, into one of which is inserted a brass or copper rod to carry the plate. By turning the pedestal in different directions, and elevating or depressing the plate by inserting the rod in different holes, the place is found where its effect equals that of the ship; after which the pedestal is removed to its station on ship-board. But by measuring the vertical from the card of the compass to the rod whereon is the plate, and the distance between that vertical and the centre of the plate, a table of the powers of any plate at any distance, may be made. Plates with such tables are now sold, so that for using them, the local attraction of the vessel only is to be determined, provided only the observations on the ship be made at a place, where the dip does not differ much from the dip of that place where the power of the plate was determined.

A remarkable circumstance in magnetism, is, that the polarizing axis is not stationary. When the mariner's compass was first invented, its variation at London was east, but it was advancing westward and continued to do so till 1823, since which time it is supposed to have been returning to the north or east. In the year 1580 it was 11 deg. 15 min. east; and in 1660 it was due north at London or had no variation. So that it appears to revolve round the earth from east to west; but whether in the same latitude, and with an equable motion is not yet determined; should it do so, it will complete a revolution, according to Mr. Barlow, in 850 years. In 1818 the dip at London was 70 deg. 34 min.; and variation 24 deg. 30 min. west: hence he computes the place of the pole to have been at 75 deg. 2 min. N. Lat., and 67 deg. 41 min. W. Long. The pole revolves at the rate of 4 deg. 14 min. in 10 years; and when it arrived at 70 deg. 23 min. W. Long. the variation would be at the greatest, and at this point it would arrive sometime in the year 1823. But by calculation the dip ought to decrease after 1818, and to be at the maximum variation only 70 deg. 5 min.; and observation shews, that the angle of the dip diminished nearly half a degree in the 5 years succeeding 1818. The dip is now therefore changing more rapidly than the variation, and will do so for 260 years, when the magnetic pole will be at 180 deg. Long. or at no variation, and the dip will be only 56 deg. After which, they will both increase for 260 years, when the needle will have its greatest easterly variation; but the dip will in-

crease till 2510, when it will be at its maximum or about 77 deg. 43min.; and the magnetic pole will again be on the meridian of London or at no variation.

The needle has also a daily variation occasioned as it appears by the heat of the sun. When the sun is on the magnetic meridian this variation is nothing; the heat being in that plane; but when the sun is on either side, he seems to repel that pole of the needle towards him. When at the magnetic east or west he has no effect: hence three times a day the needle points to the due magnetic north, that is, when the sun is on the magnetic meridian, and about six hours before he has passed it; and the maximum of deviation is three hours, before and after the transit of the meridian. As the sun repels the pole next him, the variation will be east (the north pole of the needle is always meant) before he arrive at the meridian, and west after he passes it. The sun is on the magnetic meridian at London between half-past ten and eleven o'clock A. M.; the greatest daily variation in summer is from 12 to 14 minutes, and in winter from 7 to 8. But as the sun is differently situated with respect to the earth at different seasons, his time of being at the magnetic east and west will vary all through the year; and as he advances far north in summer, in the northern latitudes there is a slight variation through the night.

7. ELECTRO-MAGNETISM.

The object of this science is to investigate the relation between electricity and magnetism, to demonstrate the cause of the magnetic phenomena, and, finally, to identify the laws of magnetic action, with those to which all matter is obedient.

What was said on Crystallization, Chap. XII. s. 15, may, in some measure, be considered as introductory to this article. We therein stated that in forming crystals the molecules arrange themselves according to their polarities, each one, when composed of only two elements, as a molecule of water, having a positive and negative pole. Caloric is composed of equal and unvarying proportions of the negative and positive fluids, and the natural tendency is to revolve round each other, as stated sec. 4. But in passing through solid bodies, or when they become latent, these motions cease, and the particles of the negative or positive fluid arrange themselves according to the positive and negative particles of the elementary substances.

But in some instances this arrangement seems to be partly overruled by foreign attractions, and the negative pole of each molecule is made to point in one direction, and the positive in the opposite, when each molecule becomes a molecule of *magnetic* fluid, and to a certain degree represents an actively magnetic body. The different states of the *electric energies* may therefore be thus defined. *Chemical Affinity* depends upon the electric fluids as inherent in the original particles of the elementary substances; *caloric* is the two electric fluids detached from the elementary particles of matter, but combined with each other; *electricity* or *galvanism* is the electric fluids both detached from the original particles of matter and from each other; and *magnetism* is the electric fluids combined with each other as caloric, and also combined with the original particles of matter as latent caloric, but the molecules are arranged, as regards their poles, in one direction.

These molecules are millions of times too small to be detected by sight, but since a magnetic needle is nearly the same in principle, we may consider a magnetic molecule as thereby represented. We have therefore to suppose the earth's surface to consist of nearly concentric layers of such molecules,—they being disposed in each layer according to the *dip*. At the magnetic equator they will be without dip, to the north of it, they will present their south poles uppermost, or externally, and, in course, will attract the *north* pole of the needle; in southern magnetic latitude the negative poles will be uppermost, and they will attract the *south* pole of the needle. But as the magnetic minerals are not everywhere equally disposed around the earth, so in some places there will be a much more perfect disposition of these molecules than in others, or a much greater number of layers: and though the whole of the magnetic shell will have a common centre, yet each of these beds will, to a certain degree, have a centre, and polarizing axis of its own.

The magnetic virtues are only possessed to any great degree by two metals, iron and nickel. Now, it is well known that iron, though we do not recollect that the same has been observed of nickel, has the greatest capacity of all known substances for latent caloric. Its magnetic properties are the most intense when soft and malleable, when its capacity for latent caloric is known to be the greatest; so that the more pure the iron the greater the magnetic powers; and this power is increased by heat, till it arrive at a red heat. However, at a

white heat, at which heat iron welds, shewing thereby that its cohesive attraction is so far overcome that its internal structure is changed, it entirely loses its magnetic properties. But it is a curious fact, that when a bar has been heated to a white heat and is left to cool in the magnetic meridian, while passing from the white through the bright red to the red, its poles are reversed, till it arrive at the cherry red, when its highest magnetic powers commence. We consider this as an electric phenomenon. Most substances while cooling are electric, and at different temperatures the charges often change sides. The natural electricity of the earth's surface is negative; the lower end of the bar then becomes positive by induction, and the upper end, which should be the south pole, negative. But the north pole of the needle is repelled by a charge of the negative fluid, and the south by a charge of the positive; hence, if the poles of the bar are determined by their attraction and repulsion, they will appear to be reversed, while in fact they are only electrical and not magnetic.

If two bars or wires of different metals be bent so as their extremities may be soldered together, forming a circle or any other figure; or if a straight bar of one metal be used, and a semicircle of another be placed in contact with the ends, and heat be applied to the joinings of the metals or to one end of the bar, the whole will be magnetic, or be one magnet, that is, the molecules will be polarized, or lie in the same direction both in the bar and wire. But in some metals treated in the same manner, the poles are reversed; and different metals exhibit different intensities. Should the bar be heated at the middle no effect is produced. Should it be alternately hot and cold in different parts, provided a wire connect a hot and cold part, and each wire communicate with the wire that joins the two poles of the bar, the power is increased: hence, it has been concluded, that for the excitation of magnetism, it is only necessary that two contiguous particles of the same metal be at different temperatures.

In magnetising needles by electricity, the shock must be given transversely, and not along the needle. So also in the galvanic battery, the two wires communicating with each end, must be joined by a third, and the needle to be magnetised must be placed across this wire. But the connecting wire itself, while the battery is in action is magnetic; that is, it will attract a large quantity of iron-filings the same as a magnet;

however as soon as the connection with the poles of the battery is broken they all fall of;—indeed the galvanic apparatus itself has the same property.

Suppose the connecting wire to be in a vertical position, then, if a needle be placed near, that has its directive powers neutralized, (that is, the influence of the earth counterbalanced by a powerful magnet properly disposed for the purpose), the needle, however placed, will remain stationary till the battery is in action, and then will arrange itself at right angles with the wire: or, if the needle is at a distance from the wire, it will dispose itself at right angles to a perpendicular let fall from the centre of the needle to the wire, so that if this perpendicular be conceived to be the radius of a circle surrounding the wire, the needle will be a tangent to that circle. If the upper end of the wire be attached to the positive pole, while a person stands with his face towards the wire, the needle being between him and the wire, the north pole of the needle will be to his left-hand. But should the negative pole be uppermost, then, the north pole will be to the right hand. Mr. Barlow thus states what he conceives to be the law of the action between the connecting wire and the needle: "Every particle of the galvanic fluid in the conducting wire acts on every particle of the magnetised needle, with a force varying inversely as the square of the distance; but the action of the particles of the fluid in the wire is neither to attract nor repel either poles of a magnetic particle, but a tangential force which has a tendency to place the poles of either fluid at right angles to those of the other; whereby a magnetic particle, supposing it under the influence of the wire only, would always place itself at right angles to the line let fall from it perpendicular to the wire, and to the direction of the wire itself at that point."

The above fact led Mr. Faraday to conceive that this was a tendency to rotatory motion, and that if properly suspended, the needle would revolve round the wire; and he finally succeeded in producing such a motion, so that either pole of the magnet revolved round the wire; or, fixing the magnet, he caused the wire to revolve round it; or, both being free, they mutually revolved round each other; and he was subsequently enabled to produce a rotation of the wire by the mere influence of the terrestrial magnetism. These, with some other facts deduced from experiments, promise to connect magnetic motions with the planetary; and to make the sciences of astronomy

and magnetism finally elucidate each other. Our limits will not permit us to enter more at large upon this subject; but what we have said will serve to point out to the reader a most fertile field for future discoveries; and to inform the young Aspirant to philosophical honours, that he need be under no apprehension lest the whole of the laurels should be reaped before he can enter the list.

If both ends of the conducting wires from the poles of a galvanic battery be inserted in a basin of quicksilver, and the pole of a magnet be held under the basin opposite one of the wires, the quicksilver will revolve round that wire forming a beautiful vortex; if the pole be held under the other wire the motion will be round *it*, but in the opposite direction; in each case an inversion of the poles of the magnet reverses the motion. Fix a wire vertically that has a loop or a hook at the end; on this loop or hook suspend another wire, of a few inches in length, loosely by a hook at the upper end; then, having a vessel containing quicksilver, let the lower end of the second wire just dip beneath its surface, and let one wire of the galvanic apparatus be in contact with the fixed wire, and the other communicate with the quicksilver; then, if a magnet be fixed through the bottom of the vessel perpendicularly in the centre of the quicksilver, or if the quicksilver be in a shallow vessel as a saucer and one pole of the magnet be held under its centre, (provided the magnet is of such length that the other pole does not interfere,) the end of the wire in the quicksilver will revolve round the pole of the magnet. Should the poles of the magnet be reversed, the direction of the motion will be reversed; or should the connecting wires of the battery be reversed a corresponding change of motion will ensue. But by a little variation, the rotation, though less rapidly, may be caused without the magnet or by the mere terrestrial influence. Let the second wire be copper or platina and about six inches in length, let its lower extremity be attached to a piece of cork so as to render it buoyant on the quicksilver, and let the vessel be about 10 in. diameter; then, if the upper wire is depressed till the lower one makes an angle of about 40 deg. with the horizon, it will revolve, while the battery is in motion, as it would do round the south pole of a magnet. By a further variation in the apparatus, which we could not well explain without a figure, the wire and pole of the magnet may be made to revolve round each other, reminding us of the motion of the sun and a planet.

CHAP. XV.

Geology.

1. INTRODUCTION. 2. GENERAL FEATURES OF THE EARTH'S SURFACE. 3. GENERAL STRATIFICATION, ENUMERATION, AND DISPOSITION OF THE MATERIALS COMPOSING THE EARTH'S SHELL. 4. PRIMARY ROCKS. 5. TRANSITION ROCKS. 6. THE PENNINE CHAIN. 7. METALLIC VEINS. 8. TRAP OR BASALTIC ROCKS. 9. VOLCANIC PRODUCTS. 10. COAL FORMATIONS. 11. NEW RED SANDSTONE. 12. THE OOLITE SYSTEM. 13. THE CHALK SYSTEM. 14. STRATA ABOVE THE CHALK. 15. DILUVIUM.

1. INTRODUCTION.

THERE are four sources whence we draw information concerning the structure of the earth: viz. revelation, tradition, electro-chemistry, and observation of its actual stratification. The *first* is contained in the bible; the *second*, partly in the same book, and partly in the faint glimmerings to be observed in the earliest profane writers, the largest mass of whose evidence, contained perhaps in the least space, is collected in Leclerc's notes to the first book of Grotius concerning the Truth of the Christian Religion; the *third*, we principally detailed in the first and second sections of Chap. XIV.; and the *fourth*, will form the principal subject of the present chapter. The parts of the inspired writings bearing on this question, are, Chap. I., the 17th and following verses of Chap. III., and the latter part of Chap. VII. of the Book of Genesis.

With respect to the Mosaic account of the Creation, it may perhaps be necessary to premise, that the design of the Divine Lawgiver, was not to teach Natural Philosophy. The idolatrous

worship of the heavenly bodies was then prevalent in the world, and the Israelitish Nation was to be kept by a divine interference to the worship of the true God: it was therefore necessary, in the first place, to shew that the Supreme Being, whom they were enjoined to worship, was no other than He who had made the sun, moon, and all the host of heaven, as well as the earth with all its conveniences:—all which the Egyptians and surrounding nations worshiped, and with whose religious rites the Israelites were already but too well acquainted. *This*, was a sure way of teaching them, the great disparity between the thing created and the CREATOR; and, consequently, how much more worthy of their homage the one is than the other. But since the earth was then under a *curse*, and man was condemned to eat bread earned by the sweat of his brow, that he might not, by having his mind continually occupied in this pursuit, forget his Creator, to whom, notwithstanding a diminution of original favour, he owed all his enjoyments,—at regularly recurring intervals that had a suitable correspondence with his powers of mind and body, he was enjoined a cessation of his toil, in order that he might renovate his piety, call to mind his derelictions of duty; humble himself before the fearful throne of the Almighty Creator; and pay the tribute of a grateful heart for his kind providence. That the imposition of these recurring intervals might not seem arbitrary, he is shewn that there is some foundation for them in the production of the visible universe. For in six periods of time was the creation of this world completed; so that, in the next succeeding period, the Almighty's peculiar work of creation being ended, He had rest, that is, he suspended his creative energy that he might admire what he had made. Hence, man having laboured for the same periods, or periods that bear a great analogy to them, should on the seventh cease from his labour:—not for total idleness, (for the Almighty never yet ceased his all-seeing providence and support of his works), but, to contemplate his origin, admire the greatness, and adore the goodness of his Creator.

The process of the first two or three days creation we described in the first and second sections of Chap. XIV. We have therein supposed, that the matter of which our Solar System is composed, existed in the state of simple substances; occupying a space in the universe reaching in all directions from the sun to half the distance of the nearest fixed stars, or as forming a chaotical mass of not less than 38 millions of millions

of miles in extent. When this was created we have not the least intimation. It had its origin from God :—but how, we know not. We are only informed, that "In the beginning God created the heaven and the earth. And the earth was without form and void; and darkness was upon the face of the deep." With respect to time, then, all this part of eternity is marked by the first evening. But, now, commences our time: "And God said, Let there be light: and there was light." Here then the elementary substances began to combine, and were immediately enveloped in a flood of light, the produce of that combination. "And God saw the light, that it was good":—that is, directed the process to fulfil its intended purpose. But as space is unlimited; and as we are assured, by the innumerable multitudes of fixed stars, that all space was equally pregnant with matter; so, it follows:—"And God divided the light from the darkness": that is, caused the matter of our Solar System to gravitate towards its centre; and consequently to separate from that which occupied the remaining space, and of which, has since been formed the fixed stars: or it might be, to leave merely an empty and therefore dark space. The preceding darkness, and the present light, therefore, constituted the *first day*; in imitation of which, the Jews count their day from six o'clock in the evening.

"And God said, Let there be a firmament in the midst of the waters, and let it divide the waters from the waters. And God made the firmament, and divided the waters which were under the firmament from the waters which were above the firmament, and it was so: And God called the firmament heaven. And the evening and the morning were the *second day*." It is only necessary here to remark, that the word *firmament* in the original, means *expansion*, or *extension* of space. We, therefore, cannot have a plainer description of this, hitherto aeriform or fluid mass of matter, by an immediate exertion of Infinite Power, or by the presence of the Spirit that brooded upon the face of the waters, being separated into different masses:—the largest for the sun and the lesser ones for the planets. In this second day, we have, therefore, these masses instead of gravitating to one centre as in the first day, condensing into a number of cometary masses. The termination or breaking up of the nebulosity is called the *evening*, and the commencement of the cometary state is called the *morning*.

The *third* day's work, at least with respect to us, was wholly

confined to that portion of matter which we inhabit; and this includes the period marked out by the cometary process, described in Chap. XIV., s. 2. At this period our Geology commences; for, now, the foundations of our earth are laid. The metals, the most weighty materials, if not combining first, at least gravitating first into an aggregate mass; and it will appear in the following pages, that, when the most weighty metals are found, it is under such circumstances as induce us to believe that they have been ejected in a fluid state or sublimed from a great depth during volcanic processes, into clefts made in the external strata. The density of the earth, also, proves that its nucleus must principally consist of these metals, since the average specific gravity of its shell, or that part of its surface of which we have any knowledge, is only 2½, while the whole mass is above 5; so that, the density of the internal parts must greatly exceed that of the external. After the metals were condensed, the respective salts of the metalloids would next form the rocky strata of the earth's surface; and when the whole was a little cooled, the aqueous vapours would begin to condense into water, and envelope the solid nucleus. But it is evident, that, when a mass of matter like the earth cooled, it would shrink to a very great degree; and being composed of very heterogeneous materials, it would shrink unequally. Another powerful cause would operate to the inequality of this process :—the uncombined electric fluids would be so abundant, that different portions of the earth's surface would be continually shook with discharges or earthquakes, which would produce indentations. These would act in obedience to the voice of God, and would occasion the waters under the heaven to be gathered together unto one place, and would permit the dry land to appear; on which the Almighty Fiat now planted the *vegetable* kingdom.

"And God said, Let there be lights in the firmament of the heaven to divide the day from the night; and let them be for signs, and for seasons, and for days and years: and let them be for lights in the firmament of the heaven to give light upon the earth; and it was so. And God made two great lights, the greater light to rule the day, and the lesser light to rule the night: he made the stars also. And God set them in the firmament of heaven to give light upon the earth. And to rule over the day and over the night, and to divide the light from the darkness: and God saw that it was good." From these words we might be led to infer that the earth was actually created

before the sun and moon. However, the text, according to the best commentators, does not sayso; but only that till this time the earth was not illuminated by the sun and moon: and according to this interpretation, our theory and the sacred text perfectly agree. For in the fourth day's process we suppose the earth to lay aside its nebulosity, or cometary state. We consider the earth's atmosphere, hitherto, to have borne a great similarity to that of the sun at present; and its luminosity to have been constituted by a great abundance of combined electric fluids, which by their combination maintained a permanent *aurora*. Though the sun and moon were both shining, the latter probably like the earth with her own light or aurora; yet their light would be so blended with the earth's own light, that there could be no distinction of day and night. Therefore, the conclusion of the cometary state formed the evening; and the commencement of the planetary, the morning of the *fourth* day.

Fifth day.—It is remarkable that no living creature was introduced upon the earth till this great superabundance of the uncombined electric fluids subsided;—and till light was properly adjusted. Not but that the Creator could have so constructed the animals, as to be capable of enduring this state of the earth; but then, their constitutions and the structure of their eyes must have been afterwards altered. It is no less remarkable that what would have been destructive to animals, was in the same degree conducive to the growth of vegetables: so that, the world would be well stored with food before there were any mouths to require it. "And God said, Let the waters bring forth abundantly the moving creature that hath life, and the fowl that may fly above the earth in the open firmament of heaven. And God created great whales, and every living creature that moveth, which the waters brought forth abundantly after their kind, and every winged fowl after his kind: and God saw that it was good. And God blessed them, saying, Be fruitful, and multiply, and fill the waters in the seas, and let fowl multiply in the earth." Of the fowls of the air, we shall take little farther notice;—but Geology affords ample proof of the blessing of the inhabitants of the deep, for they must have abounded beyond all conception, since we find whole ranges of mountains, as well as thick strata of the plains in some cases, almost entirely composed of their exuviæ.

Sixth day.—We have now the earth in a fit state for the habitation of terrestrial animals; and, no sooner is it fit for them than they are, by an extension of the same creative energy, brought forth. "And God said, Let the *earth* bring forth the living creature after his kind, cattle and creeping thing, and beast of the earth after his kind: and it was so. And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind, and God saw that it was good." We have now completed a third step in the *rationale* of the creative energy: the first being the concentration of matter; the second, the imposing on it vegetable life; and the third, the reducing of it under obedience to the laws of animal life. But an exertion of a different nature is yet to be made; and a different form of expression is accordingly adapted, plainly pointing out a wide distinction between mere animal life, and the *principle* which regulates the action of that *being*, who was to have dominion over the other creatures, which God had made. "And God said, Let us make man in our image, after our likeness: &c.—And the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life, and man became a living soul."

With respect to the question whether we are to consider these periods of evenings and mornings as consisting of 24 hours, it is not our design to give any decisive opinion. It is certain the first two cannot be considered as defined by the diurnal revolution; since the sacred text declares that the sun and moon were not created, or, at least, that the earth was not enlightened by them. If we consider the process in all respects the same with the concentration of our present nebulosities and comets, then, we must certainly allow an immense period to each day; but if we ascribe the creation of our Solar System to a more *peculiar* exertion of Divine Power, then, it would be limiting Omnipotence, to say that all this might not be done in the short space of six of our days.

We have now traced the progress of the divine works to that period when the Creator rested from his labour; and man, for whom this labour seems to have been principally undertaken, is placed in this new abode, thus, fashioned, furnished, and rendered delightful for its inhabitant. The question that here bears on Geology is *this*;—the animal kingdom depends for its support on the vegetable kingdom, and this again on the

soil, moisture, air, and heat. The soil, therefore, is what principally concerns us. If it was thus favourable to the vegetable tribes, may we not look for a suitable correspondence in its composition? But we have the most positive evidence that the arrangement of the inhabitable parts of the earth's shell, has, since the creation, been completely changed. We can, therefore, only expect to find its component materials. Now by experiment it is found that the most favourable composition of soil for the growth of plants, is, about 4 parts silica, 3 clay, 2 lime, and 1 magnesia, sulphur, soda, potas, and oxide of iron. If we take a survey of the materials composing the strata that seem to have been new arranged since the creation, we shall find them almost entirely composed of the above ingredients; and as nearly as we can judge in the above proportions. At the creation, then, we suppose that these materials were regularly blended in one thick shell or stratum around the earth's surface; by what dreadful calamity they became otherwise we now proceed to enquire, and we think there are some intimations of it in the following texts. "And unto Adam he said, Because thou hast hearkened unto the voice of thy wife, and hast eaten of the tree, of which I commanded thee, saying Thou shalt not eat of it: *cursed* is the *ground* for thy sake; in sorrow shalt thou eat of it all the days of thy life; Thorns also and thistles shall it bring forth to thee; and thou shalt eat the herb of the field. In the sweat of thy face shalt thou eat bread, till thou return unto the ground, for out of it wast thou taken: for dust thou art, and unto dust thou shalt return.—Therefore the LORD GOD sent him forth from the garden of Eden, to till the ground from whence he was taken. So he drove out the man; and he placed at the east of the garden of Eden Cherubims, and a flaming sword which turned every way, to keep the way of the tree of life."

The curse of the Creator opposed to the various blessings pronounced in the first chapter; and the "thorns and thistles," meaning all weeds or noxious plants and prickly shrubs, contrasted with the "Every tree that is pleasant to the sight, and good for food, the tree of life also in the midst of the garden and the tree of knowledge" are clear indications of some more stupendous change of a geological character, than we have perhaps been accustomed to consider them. The cherubims, and the flaming sword, (*sword-like* flame, or *pointed-flame,* for the original word will bear these variations), which turned every way, seem

to be intimations of some dreadful catastrophe of an igneous nature. By the curse and the destruction of the pleasant trees, is perhaps meant, that complete revolution of the earth's external shell, which seems to have taken place at the formation of what are considered the oldest rocks. This revolution might principally consist of local or partial subsidences of the earth's external shell, (as explained in the following sections), making deep cavities or indentations, into which were swept the vast vegetable produce of the earth, viz. "The pleasant tree," &c. &c. and piled in alternating beds, with the earthy materials.

By the flaming sword we may understand the vast valcanic processes, of which we have abundant proof that the earth, since the creation, has been the theatre, especially while the primary and transition rocks were forming. These, as will afterwards be explained, might be the mere result of the above subsidences.

The length of time, the above process would require, forms another subject for our consideration. The Sacred Writings allow a space of 1657 years. Now all the rocks from the primaries to the New Red Sandstone, we consider of very hasty formation. The organic remains by which they are chiefly characterized, we suppose to have been formed in the third, the fifth, and sixth days of the creation, and therefore prior in one point of view, to the above period. Now, as we suppose the *curse* and its consequent calamity to have almost immediately succeeded the creation, we shall have the principal part of the above period of 1657 years for the formation of all the rocks subsequent to the New Red Sandstone; a space of time we think sufficient for the whole; and at the conclusion of which, we consider our continents to have been fixed nearly in their present state.

But we have another revolution pointed out in the Sacred Writings, whose vestiges, though not indicative of so tremendous a catastrophe as the above, yet, because they lie on the surface of the other are more apparent. The one alluded to is called Noah's Flood or the *Universal Deluge*, and its principal evidence is considered to rest upon the great number of organic remains, chiefly contained in the diluvial beds of rivers, and in other places resting upon the surface of the formations, beneath or blended with the diluvium. These remains differ from those imbeded in, or forming a component part of the different rocky strata; and they have belonged to animals, dif-

fering, or of species altogether different from animals of the present day. The agreement among themselves, and their universality are such, that, as Cuvier observes, "had we never heard of such an event from Scripture or any other authority, (as a *universal deluge),* Geology of itself must have called in the assistance of some such catastrophe to explain the phenomena."

In presenting the above interpretation of the sacred text, far be it from the writer to say positively that this was actually the process; or that the evidence of the authenticity of the sacred writings is any way involved in the stability of his theory. The Bible contains faint glimpses of what has taken place; but the manner how, is left to exercise the intellectual faculties of mankind; and among the various conjectures that have been formed, the above are offered as those of one humble individual. The rage of a certain party of would-be-thought philosophers to seize on every new discovery as a handle against Revelation, and their invariable defeat, form a very convincing proof of their mental delusion, and of the certainty that the scripture is the word of God, and that no power shall prevail against it. While on the contrary, it is truly painful to see the feverish anxiety manifested by some sincere Christians on the announcing of any new theory of *nature*, lest it should affect the grounds of their faith. To both the author would say once for all, that they may rest assured, that Revealed Religion is on too solid a foundation to be shook by any system of Physics however *wild:* and they may be no less sure, that if the present theory be a true one, it will eventually add another arch to that bridge which will finally connect natural with revealed religion. But, on the contrary, should it be false, it will fall to the ground and be forgotten; while Revealed Religion remains unaffected, firmly supported by its own proper evidence. An evidence amply sufficient for the conviction of any man of reflection and upright intentions; and which no doubt the Creator of the human mind deems sufficient for that kind of probation to which it pleases him that man should be submitted.

2. GENERAL FEATURES OF THE EARTH'S SURFACE.

If we take a geographical survey of the earth's surface, we shall find the sea covering somewhat more than two thirds of the whole globe. The principal part of the land is divided into large continents, disposed as it were on the opposite sides of

the globe to counterbalance each other. They form narrow points towards the south, increasing in breadth as they reach the north, till their bases about the artic circle almost join. This occasions a much greater expanse of water in the southern than in the northern hemisphere. But the sea is found to be much shallower, or at least in most parts, in the former than in the latter, and it is likewise interspersed with innumerable islands. As far as can be deduced from the observations of navigators, land does not extend to either pole, but at each pole is supposed to be an immense cupola of ice.

Many of the islands in the Great South Sea consist of rocks of coral, which are formed by a species of shell-fish, and which, in length of time, and perhaps by the subsidence of the general level of the sea, are elevated above the surface of the water, and become encrusted over with soil formed by the united action of rain and the atmosphere. Sea shells consisting of lime and animal matter contain the basis of the richest soils. Vegetable matter with the excrement of birds now accumulates, till in a few ages they become covered with trees of the largest growth,—when at length man here fixes his abode and calls himself lord of the creation. Captain Cook and other navigators describe several such rocks or islands as in the act of forming beneath the surface of the water, rising from the bottom somewhat in the shape of a mushroom, which, since sounding is useless, make the navigation very dangerous. Similar rocks abound also in the Red Sea, which spreading along its bottom give a reddish tint to the water; whence its name.

Islands at the mouths of large rivers are mostly formed by the deposition of alluvial matter, washed down by the river, and lodged there by the reaction of the sea. The Delta at the mouth of the Nile is of this kind, and it is said the sea retires from Rosetta about a mile in 40 years. There are also islands of the same formation at the mouth of the Ganges, the Danube, the Po, and one recently formed at the mouth of the Humber. The island of Trinadad at the mouth of the Oronoko is chiefly of this formation, as well as a great part of the adjoining coast around, and between that river and the Amazon. But the river Mississippi is the most remarkable instance of this kind. Such is the quantity of alluvium brought down this river and deposited in its channel, that it may be actually considered as running along the top of a hill; for its present bed is 24 feet above the adjoining valleys. The base is three miles in its average

diameter, and reposes on swamps which are, near the sea-shore, about 9 feet above the marshes. This alluvial formation extends 250 miles up the river. Such is the quantity of drift wood and other alluvia, that, in one of the branches of its mouth, several hundreds of miles are converted into solid rafts; once in every two or three years, these disappear—either under the water or sandy alluvium. But they are continually changing the bed of the river. No less than 36 cubic miles of alluvium are supposed to be annually floated down this river. The large raft in the Red River is 60 miles in length and 15 in breadth. In places the river disappears beneath these rafts, and afterwards rises to day; and sometimes they are buried beneath the river: hence, the origin of coal and bituminous substances. Since the discovery of America the mouth of this river has retired 50 miles. Such formations as this are not uncommon in our present continents at a considerable elevation above the present level of the sea.

In some alluvial tracts the annual accumulation may, to a certain degree, be ascertained; thus serving as geological chronometers, by which we may in some measure ascertain how long our present continents have been in existence. This is most remarkable in the alluvial tract at the mouth of the Po. It has been ascertained to have a regular rate of increase in a century; and the line of the original coast is capable of being defined. It is evident, therefore, that the length of time in which this tract has been in forming may be determined; and it is very satisfactory to find that the period of its commencement is that which we assign to the Noachian Deluge.

Another cause of the formation of islands are the conflicting currents or tides of the ocean. The Dogger sand-bank may be adduced as an instance of this kind, which promises finally to rise above the sea and become habitable earth. Some islands are totally the work of submarine volcanoes. But with these few exceptions, islands differ nothing from continents, being merely hills or the summits of primary mountains whose adjoining valleys are lower or nearer the earth's centre of gravity than the valleys of the continents, and therefore the water finds its level in them. The largest island is New Holland; but the continents are equally surrounded by water, and are therefore islands on a larger scale.

The most prominent features of the continents are the *mountains*. And of these the Himala, lying behind our possessions

in the East Indies, are by far the most lofty. According to Captain Blake, (though the accuracy of his admeasurements has been questioned), the highest of them are between 5 and 6 miles above the level of the sea; almost a mile and a half higher than Chimboraco the most elevated point of the Andes, which till lately was considered as the loftiest pinnacle of the globe. Little is known of the geology of these Asiatic mountains, except that marine shells are found among them at considerable elevations. The Andes, in many respects, are the most important range of mountains in the world. They run the whole length of South America; and, on a less magnificent scale, through a great part of the Western side of North America. Like all mountainous regions they abound in volcanoes; and as more of the precious metals have been found among the Southern Andes, than among all other mountains put together, they have consequently become the most known. On account of their running through the torrid zone, they also give rise to the largest rivers in the world. The Alps are the loftiest mountains in Europe. The most extensive range in Africa are the mountains of the moon, which run almost entirely across the continent. They have considerable elevation, but the exact height, it seems, is not well known;—that part of Africa being as yet unexplored by Europeans. Mount Atlas has consider- elevation; but the Peak of Teneriffe is the most exalted point in Africa.

Mountains, in a geological point of view, may be divided into three classes;—the primitive and volcanic; the transition; and the secondary. But these distinctions bear no relation to their height; since granite, which is the chief rock in all primitives, is found at very low levels in the eastern parts of North America, and at no considerable elevations in the British Isles. However, with respect to their own districts, the primitive are invariably the highest. In most cases the primitive range has a parallel range of transition, as it were either surrounding it or within it; the transition has also parallel ranges of secondary. The transition is therefore less elevated than the primitive, and the secondary less so than the transition. But if we compare a suit of these ranges in one part of the world, with a suit in another, we shall find no agreement; though the three orders generally have the same proportion of elevation among themselves.

Table of heights in feet from the level of the Sea.

West end of the Tarpean rock	151
The Palatine Hill	166
Arthur's Seat, from Leith pier head	803
Lake Geneva	1,230
- its greatest depth	393
Mount Vesuvius, base of cone	2,021
Saddleback	3,048
Ben Lomond	3,180
Skiddaw	3,270
Helvellyn	3,324
Cross Fell	3,390
Pendle	3,411
Table Mount (Cape)	3,454
Schehallien	3,461
Snowdon	3,555
Pennygant	3,930
Mt. Vesuvius, mouth of crater	3,938
Ingleborough	3,987
Whernside	4,050
Ben Nevis	4,350
Hecla	4,887
Mount Jura	5,523
Summit of the Mole	6,113
Mont Cenis a la poste	6,261
Monte Velino, Appennines	8,397
City of Gondar, Abyssinia	8,440
Canigou, Pyrenees	8,544
Summit of Mount Cenis	9,212
Pic du Midi, Pyrenees	9,300
Quito	9,377
Monte Viso	9,997
Glaciere de Buet	10,124
Etna	10,954
Pike of Teneriffe, Borda	11,022
Do. old estimate	15,084
Pic d' Ossana, Pyrenees	11,700
Aiguille d' Argentiere	13,402
Ophir, in Sumatra	13,842
Monte Rosa, Alps	15,084
Summit of Mont Blanc	15,669
Pinchincha	15,670
Antisana	19,290
Chimboraco	19,595
Himala, according to Blake	
Peak without a name	21,935
Chandragiri, or Mountain of Moon	23,007
Peak without a name	24,108
Swelagar or Nepal	25,261
Dhwalagiri, Ghasu Coti, or White Mountain	28,015

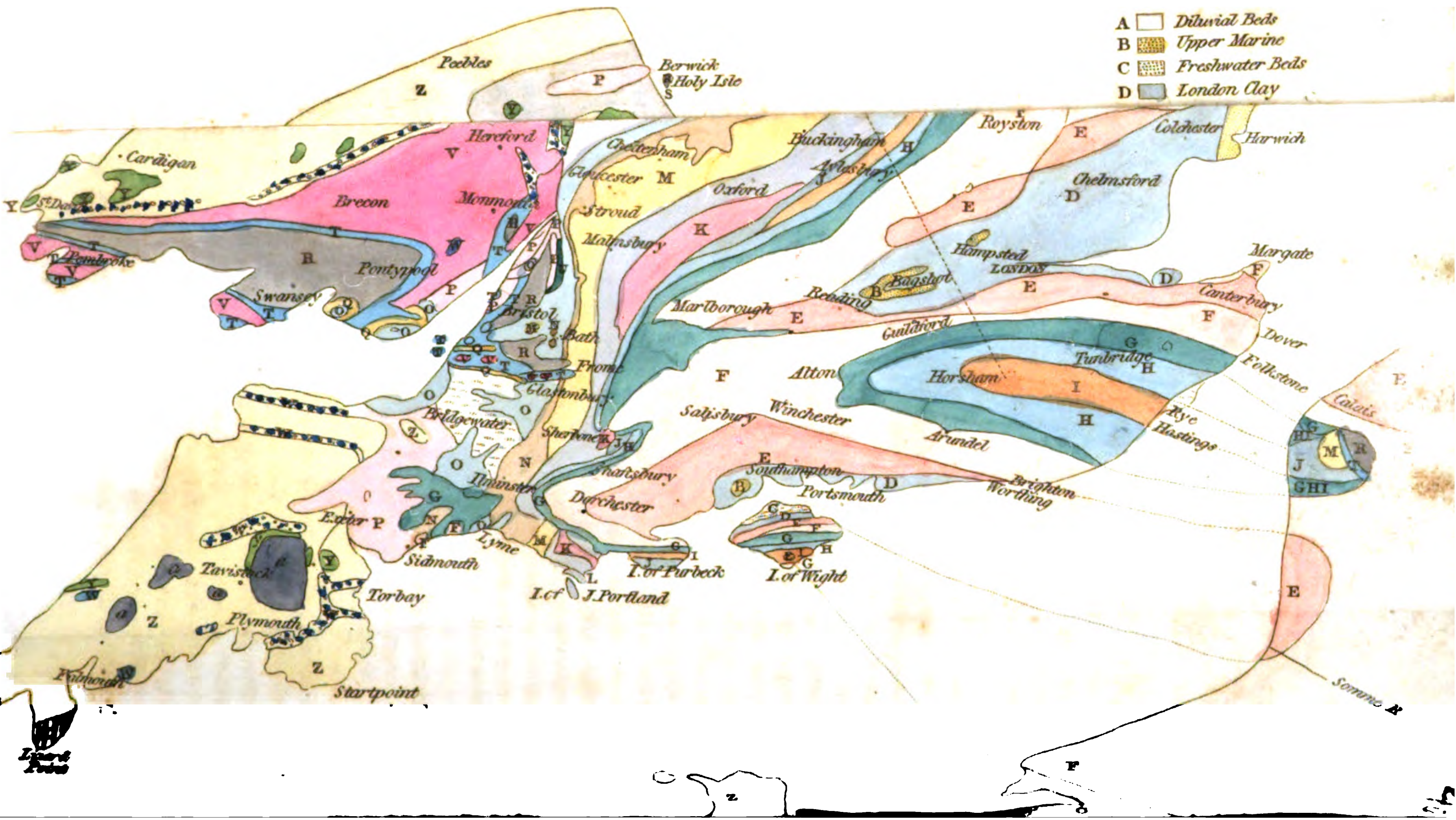
The next grand feature of the earth's surface are the *Rivers*. The origin of rivers is in the vast evaporation from the sea, carried principally to the mountains by the clouds, and there, by causes hereafter to be explained, the vapours are precipitated in rain. A great deal more water is carried over the land than is needed for the animal and vegetable kingdom, and the superfluity is returned to the sea by the rivers. The quantity of water therefore that a river returns will depend upon three circumstances :—namely, the height of the mountain, the climate and the distance from the sea. The last circumstance principally depends upon the range of the mountains; for when they range from north to south the eastern declivity is a gradual slope, while the western is steep and precipitous. If they range from east to west, then, in northern latitude the northern declivity is a gradual slope, while the south is steep; and vice versâ in southern latitude, (but this determination is by no means so strongly marked as in the former case); hence, the rivers on one side of such mountains must be long, winding, and large; and on the other, short and rapid.

Of all the large rivers, the Amazon enjoys the above three advantages in the most eminent degree, and is consequently the largest river in the world. Its course is 4000 miles, and it discharges itself into the Atlantic by a channel of 150 miles in width, so that its width is almost equal to the length of our largest British rivers.

The Himala mountains range generally from east to west, and therefore the southern rivers are rapid. Though some of them, as the Ganges and Indus, are of considerable length; yet, they are short when compared with the northern or north-eastern rivers from the same mountains. The Ganges has a course of about 1400 miles; but it must be observed of this river, that it partakes a good deal of the easterly direction. It has at some time worked its way through the Himala, and there forms a cataract, which is upon a more magnificent scale than the more noted one of Niagara. But the two great Chinese rivers, the Hoanho, or Yellow River, and the Kian Ku, that have their rise on the northern or north-eastern declivity of these mountains, and take an easterly direction, the former inclining with a curve to the north and the other with a curve to the south, and then discharging themselves into the Yellow Sea within 100 miles of each other, are said to dispute the pre-eminence with the Amazon itself. The great northern rivers of Asia seem to be little known.

The most noted river of Africa is the Nile. It takes its rise among the "Mountains of the Moon," which run from east to west in north latitude; it is therefore not less than 2000 miles in length. Next to it is the Niger, which has its rise on the western coast near Sierra Leone among the north west branches of what perhaps may be considered an extension of the Mountains of the Moon. It appears to cross the centre of Africa, under a variety of names, and to form a principal auxiliary stream of the Nile; but to determine this, has cost the life of many an enterprising traveller.

The Wolga is the largest river in Europe, and its course is southerly, apparently forming an exception to our rule, but not to our theory. This river, as well as the Don and Dneiper, has its rise in the extensive forest of Volkonski, which extends almost from Smolensko to Moscow: after winding a course of 2000 miles the Wolga discharges its waters into the Caspian. The second river of Europe is the Danube; the others are too numerous to particularize.


A Diluvial Beds
B Upper Marine
C Freshwater Beds
D London Clay
Peebles
Berwick
Holy Isle
Cardigan
Hereford
Brecon
Monmouth
Pembroke
Pontypool
Swansea
Bristol
Bath
Frome
Glastonbury
Bridgewater
Sherborne
Ilminster
Exeter
Sidmouth
Lyme
Tavistock
Torbay
Plymouth
Falmouth
Startpoint
Cheltenham
Gloucester
Stroud
Malmsbury
Oxford
Buckingham
Aylesbury
Royston
Colchester
Harwich
Chelmsford
Hampsted
LONDON
Bagshot
Reading
Marlborough
Margate
Canterbury
Dover
Folkstone
Guildford
Tunbridge
Horsham
Alton
Salisbury
Winchester
Arundel
Rye
Hastings
Shaftsbury
Dorchester
Southampton
Portsmouth
Brighton
Worthing
I. of Purbeck
I. of Wight
I. of Portland
Calais
Somme

The last feature of the earth's surface, which we shall mention, are the lakes. These are indentations or subsidences of the surface of our globe, and may be considered as occupying the vast gap between the ocean and the mere bog. If the indentation is connected with the ocean, as the Black Sea with the Mediterranean, or as the latter with the Atlantic, it is called a sea, gulf, or bay. If it is no otherwise connected than by a river, as the great American Lakes and the river St. Lawrence, or not at all, as the Caspian Sea, it is then considered as a lake.

The Caspian Sea is said to be at a lower level than the ocean by 306 feet, and its waters are salt. It has been sounded with a line of 450 fathoms, and no bottom found. Within the last half century the waters have risen to a much higher level, and have consequently made great inroads on the adjoining country.

Next to the Caspian the Lake Superior, North America, is the largest inland expanse of water in the world. The surface of its water is at several hundreds of feet above the sea level. It contains many islands, one of which is above 100 miles in length. The water is sweet and remarkably clear, and is said to rise and fall 3 feet once in 15 years. A similar periodical change has been observed in the Caspian; but it completes a revolution in one quarter of the time.

It would far exceed our bounds to particularize all the principal lakes. Their formation may in general be ascribed either to the subsidence of an old volcano, or to partial subsidences of the earth's surface, surrounded by a rock of too compact a structure for the water to abrade or perforate. For lakes with mineral waters, see index.

3. GENERAL STRATIFICATION, ENUMERATION, AND DISPOSITION OF THE MATERIALS COMPOSING THE EARTH'S SHELL.

Our actual knowledge of the earth's internal structure and composition is very limited, being only what we derive from these three sources: viz. mines, the excavation of rivers, and the identification of the outcrops or bassets of strata. The deepest mine in the world, which is that of Truttenberg in Bohemia, is only 1000 yards below the surface, while to the earth's centre is 4000 miles. The deepest mine in England, a copper mine at Ecton, Staffordshire, is only 472 yards; and the

deepest coal mines in Northumberland and Durham do not much exceed 400 yards. We know nothing of the depth of volcanoes; but as they eject no substances which do not come under our daily observation, we derive no additional information from that source. The excavations, caused by the course of rivers, often lay bare strata of rock that are far beneath the surface of the adjoining plains or mountains, and so far discover the earth's internal structure. But the source of the most extensive knowledge, and that which constitutes the foundation and superstructure of the science of Geology, is the *indentification* of strata.

So far as man actually knows of the earth's internal structure, it consists of strata of different kinds of rocks, overlying each other, though seldom or ever horizontally;—for it is invariably found, that an under stratum of one district, at a certain distance in another, rises to the surface (provided the latter is more elevated) and becomes the external stratum. It is then said to *crop out* or *basset*. The angle which this stratum makes with the horizontal plane is called the *inclination* or *dip*. The primary rocks are generally almost perpendicularly stratified; the transition are often so, and are besides variously arched, contorted, or crumpled together; but the secondaries in some places almost approach the horizontal stratification. However, such is the disturbed state of the strata in certain places among the latter, and apparently of the undisturbed among the two former, that there are instances of perpendicular strata of the latest secondary formations, as in the London Clay of the Isle of Wight, as well as of nearly horizontal strata in the primary or transition, as in the Old Red Sandstone in some parts of Scotland. It is admitted that all strata have been formed horizontally; how they became otherwise, is the object of speculative geology to teach.

We have two means of identifying a stratum or rock: viz. its *internal arrangement* and *composition*,—and its *organic remains*. Now if we find a certain rock at the surface, or at a short depth beneath the soil, for instance about the centre of England, of a certain structure and composition, or internal and external appearance, containing certain organic remains, which we know no other rock in England contains; and we find in France a rock of the same structure and composition or internal and external appearance, accompanied by the same organic remains, the subjacent and superincumbent rocks in each place being the

same; and if at intervening places in sinking wells or pits, in the deep excavations of rivers, or in the cliffs that line the coasts of the interjacent sea, the same rocks with the same organic remains be found, though in each place the inclination of strata or the elevation above the sea level widely differ,—we conclude that rock to belong to, or to be a continuation of, one and the same formation.

With respect to the organic ramains;--they are not indiscriminately dispersed throughout the rock formations; but are disposed as it were in families;—each formation containing an association of species in many instances peculiar to itself, partially differing from those in the adjoinging formation, and widely differing from those of a more distant one. And these accompany it throughout its course, so that, at whatever distinct points of the same formation, we are sure of meeting the same general assemblage of fossil remains. In comparing these remains with the animals and plants which at present occupy the waters or cover the face of the earth, we find a great part of the genera and a vast majority of species entirely different. Indeed with the exception of those contained in the most recent bed, (the crag,) nine out of ten fossil shells belong to species not now known to exist.

The organic remains may not improperly be assorted into four æras, though each of these, except the last, must include a number of ages. The *first* æra occupies the space between the primary rocks and the new-red-sandstone. In the transition we find, though very sparingly, corals, encrinites, and testacea, with a few imperfect vegetable impressions. Nearly the same abound in the mountain limestone, and they disappear in the coal strata that rest upon it; but here occur abundance of vegetable remains, viz. ferns, flags, reeds, and trees, all of unknown species. The magnesian limestone rests on the coal and contains marine remains somewhat peculiar to itself. The *second* æra commences with the lias and ends with the chalk; it includes a number of ages as determined by the regular gradation of its organic remains. To different species of the above, we have added crustacea, vertebral fishes, and marine oviparous quadrupeds. The *third* æra commences with the plastic clay and ends with the upper marine. It also includes two or three ages, and contains a vast multiplication of species of a few genera of the second æra—with species of a few genera that now exist. And though we have in this æra intervening beds

of fresh water formations; yet, we seem to have the remains of no higher order of animals, than amphibia. The *fourth* æra is marked by the remains of numerous land quadrupeds of unknown species, mixed with strata of gravel, indiscriminately covering all the formations, and having every character of being the result of a general deluge.

The science of Geology is as yet but in its infancy; and the only part of the earth's shell in which the arrangement of strata has been reduced to any thing like a system, is, the part included within what has been denominated the Great Basin of Western Europe. This basin is included on the north by the Scotish Grampians and Highlands, on the west by the mountains of Cumberland, thence ranging along the Welch mountains by Devonshire and Cornwall. From England it crosses the British channel to Betagne, La Vendee, and the Pyrenees. The Alps form the eastern boundary, to the north of which, the basin extends into Eastern Europe. The northern boundaries take in the mountains of Finland and Norway. We do not suppose that this circuit was ever a complete range of primary mountains, or formed the actual edge of one great subsidence; but that it is composed of the edges and even centres of many subsidences; and generally includes a space occupied by transition and secondary rocks; the latter principally extending throughout the whole area.

Within the range of the primary mountains, is the transition range;—viz. the Cheviot in the south of Scotland. The primary and transition of Cumberland, Wales, Devonshire, and Cornwall, seem often intermixed in one irregular range. But having traced the general outline, we must refer the reader to the geological map for what the basin may be said to contain. This map represents a western corner of the basin; but the remaining part of it occupying France and Germany, contains nearly the same materials, and arranged in the same order one above another. Only the formations in different places greatly differ in thickness, and some of them, with minor strata of the whole, sometimes thin out and totally disappear. Though certain of them always retain their parallelism, or the same inclinations to each other, yet the whole series as taken at different points in the basin, are inclined at all angles from that of the nearly horizontal to the vertical.

The bottom of this basin, as it regards England, is at London; there being no formation of any considerable extent

posterior to the London clay. This is called the London basin, and its strata are nearly horizontal. But the same formation is found in the Isle of Wight and the adjoining Hampshire coast, where its strata are nearly vertical. This must have been occasioned by a partial subsidence posterior to the formation of the London clay;—and it forms what is called "the Isle of Wight basin." Paris is situated at the centre of another basin, which seems o agree with that of the Isle of Wight; and there are several others of the same age and character; so that these may be considered as smaller basins within the larger. (see *Fresh-water* formations).

For an enumeration of the contents of the larger basin, we refer the reader to the map; informing him that geologists have supposed, that if we were to descend perpendicularly into the earth at London, or through the formation D, we should perforate all the formations in the order in which they are placed, till we finally arrive at *a* or granite, below which man has never penetrated. However, it is not supposed but that some of these might be wanting, particularly those between Q and V, and between V and Z. Therefore, if we could remove the formations, each would be a distinct basin. They may consequently be considered as so many basins of different sizes placed within each other; and London or Paris may be assumed as the point at which man's knowledge, in the direction of the earth's centre, is the most extended. Bakewell supposes its depth to be about 8 miles.

A person travelling from London to Cornwall, to Wales, to Cumberland, or to Scotland, must evidently pass over the out edges of the above basins, or the outcrops of all the formations, and the map represents them as they appear at the surface. Now it must be recollected that the map does not illustrate the comparative thickness of the formations, but rather their inclination or dip:—for, supposing a stratum of 100 feet thick—if vertical, it will only form a zone of 100 feet in width, but if it be nearly horizontal, it may extend many miles.

Having premised so much respecting the materials and their disposition in this basin, we now come to a more perfect developement of its probable formation. For this purpose, we revert to the original state of the earth, when it was just emerging from its cometary form, and the waters were gathered into one place and the dry land appeared. Now supposing the earth so round that all parts of its surface (allowance being

made for its spheroidal shape) were at an equal distance from its central point of gravity;--but, being composed of heterogeneous substances, which contracted while cooling, unequally, and also of substances of different conducting powers, which discharged the electricity in shocks, like our present earthquakes, we should then have indentations made in the earth's surface into which the waters would drain. Supposing these indentations bore the same ratio with respect to level, that our present seas bear to the less elevated parts of our continents;—now as the earth's surface, by reason of its being cooled in the presence of violently agitated water, must have been less compact than at present, into these indentations would be washed vast quantities of earthy materials, which would give a waved-like appearance to the stratification. The bottoms of these seas now, became stocked with shell-fish, and these mixed with other matter laid the foundation of our primary, transition, and mountain limestone. The continents likewise became thickly beset with the vegetable kingdom, but were also interspersed with lakes, into which the vegetable substances, perhaps in the manner of some of our present peat bogs, were carried. While things were in this state the great revolution, constituting the *Curse*, as stated sec. 1, took place.

Now supposing this to consist of a great, but uniform, though not simultaneous concentration of the terrestrial mass: or, that the continents now subsided generally, till the parts not previously disturbed, were at an equal distance from the central point of gravity, with the original bottom of the indentations. It is evident that the places of the original indentations must have all the materials upon them which had been swept into the cavities, with all the spoils of the inhabitants of the deep. They must therefore exhibit considerable excrescences on the surface of the globe, constituting considerable ridges or mountain ranges. In this manner, may have been formed, the class of rocks belonging to the first æra of organic remains. The continents must then have changed place with the sea, and consequently none of the earth's primitive surface is now remaining.

But as we have supposed the first indentations to contain a large quantity of diluvial matter as well as the weight of the water, and all this supported by a mere shell, resting upon a fluid nucleus, it is evident that on the continents the internal fluid matter would only have the weight of that crust to support, while the same matter beneath the sea, would

have the weight of all that ocean and its contents to sustain. In such a concentration as the above, may we not suppose that the seas and their load would partly press into the fluid nucleus, and force it up round the edges of those seas? And would not the expressed matter be in the form of our granitic rocks, that is unstratified, while the others which were originally stratified horizontally, would by such subsidences have their strata inclined at all angles? But as all this would be accompanied with all the dreadful concussions of earthquakes, that is, with inconceivably great discharges of electricity through the whole mass;—may we not expect to find the rocks of this æra, as we certainly do find them, in the greatest possible confusion, broken through as by electric shocks, contorted, crumpled, rent, and full of clefts and caverns?

But supposing the above revolution caused a complete change of the earth's suface, and the primary mountains still resting on a heated nucleus, the waters, (seeking the surface of the primitive continents where they were not elevated by a forcing aside of the fluid nucleus,) would farther destroy the balance of the earth's gravity, and acting as it were on the long arm of the lever, would produce other subsidences, and would cause the solid shell to give way again among the primary and transition ranges. But as we must now suppose the earth to be solidified to a greater depth, that matter which these pressed out must come from a greater depth than the granite came from. These then produced the serpentine, syenite, the metallic veins and those trap formations, which pervade the rocks of the first æra.

But among the primaries thus formed, we do not suppose that any have maintained their original elevation. The Himala are little known, so that the Alps perhaps have been the most stationary, since granite is found at the top of Mont Blanc 15,686 feet high, while it is not higher among the Andes than 11,500 feet, the rest being syenite, porphyry and volcanic matter; while the primary mountains in North America are little above the sea-level, and others no doubt have finally disappeared beneath the ocean. We have what amounts in a geological point of view to positive proof, that the British continent has subsided a great deal below its pristine level. This proof is as follows:—the oolite on Mount Jura has an elevation of 4000 feet, while in England it does not reach 1200 feet. Now according to every geological theory, these were deposited

from the same flood and at the same time; and consequently at the same level, forming the bottom or lining of the same sea. The middle of that sea or intervening space has greatly shrunk, (witness the rents of Auvergne?) and the western boundary has been involved to a less degree in the same effect, while the eastern limits have remained nearly stationary.

We have yet to mention what are called *slips*. These are chiefly found in rocks of the first æra, and consist of clefts reaching across or along the mountain. Such clefts seem to have extended to the fluid nucleus, and when the subsidence was taking place, one side of the rock sunk deeper than the other, or one subsided while the other remained stationary. These slips almost always accompany metallic veins, and whin-dykes, though they are very common where there has been no ejection from beneath. In Derbyshire is a slip in the mountain limestone, where one side of the rent has subsided 900 feet. Many awful precipices in all the formations of the first æra are to be attributed to such slips. Now all geologists agree that either one side must have sunk or the other must have been exalted. Though we might perhaps find force sufficient to exalt it; yet when it was raised, we perhaps might find some difficulty in introducing a support to retain it there:—since that very force which exalted it, would equally oppose the entrance beneath of all other matter; or rather, the mountain itself would press with a greater power than any foreign body. The same reasoning will apply to the primary mountains, which have sometimes been said to have been elevated by an internal volcanic force.

We are now arrived at the period when the rocks of the first æra only, formed the earth's surface, and we suppose the proportion between land and water might be nearly as at present. The situation of the Atlantic ocean might therefore be occupied by an immense continent of primary, transition, and Pennine rocks; the coal measures might form the sea shore, the sea would consequently overflow nearly all Europe, (or we should have our basin filled with water,) and the new-red-sandstone or red marle would form its bottom. Now supposing many subsidences to take place successively in this Atlantic continent, ejecting vast quantities of liquid matter each time, while the sea was each time making fresh encroachment upon it. The water would, therefore, carry away a great deal of those materials, and deposit them in the European basin, would thus

form each series of rocks in the two following æras, commencing with the *lias* and ending with the *London clay*. But at the same time that these continents subsided, they would make deep indentations on the earth's surface, into which the sea would rush; consequently the surface of the sea would sink to a lower level, and would recede from its shores with instantaneous subsidences, carrying vast quantities of the looser materials along with it, and scooping out deep trenches on the earth's surface. Now after one subsidence had taken place, as it might be some time before another succeeded, the lias for instance, would, for a certain period, form the bottom of the sea as well as some part of the shore; hence its peculiar organic remains.

These secondary formations would be originally deposited each at a lower level than the one immediately preceding it, and they would form a regular slope from the new-red-sandstone downwards. But several of them now form a range of hills, at a much higher elevation than the adjoining older ones on which they rest: for instance, the inferior oolite presents a bold and precipitous escarpment along the lias. This would be a natural result of the difference of chemical attraction existing among the component materials. The lias is composed chiefly of alumina and lime, which have a much less affinity for each other than silica and lime, the component materials of the oolite. Therefore, previously to the ocean retiring from these, the oolite would be agglutinated into a firm rock, while the lias would remain a mere loose puddle; consequently, the lias to a great depth would retire with the receding ocean, while the oolite retained its ground. In like manner were probably formed the secondary features of the earth's surface; viz. the undulations of hill and dale which diversify the secondary districts, and serve as channels for small rills and rivulets; while the trunks of the chief rivers, though assisted by this, seem to owe their particular determination, to local subsidences of the surface.

Thus, we have supposed the primary and transition rocks to have been thrown together in the presence of heat, while, those of the second æra were never affected by heat since their deposition from water. The former would therefore retain some of this heat till after the latter were deposited, and as they gradually lost it, they would shrink or subside: they therefore do not keep their original elevation, with respect to the secondary. Hence orriginated the deep indentations, and the

lines of lakes, that invariably occupy the space between the transition and secondary ones. It has long been an established fact among naturalists, that the highest mountains lose a foot of their elevation every century.

On no other theory have the presence of blocks of granite found on the top of Mount Jura, and in other like situations, been accounted for. Jura is a secondary range, and no granite of the same kind is nearer than the top of the Alps, separated from Jura by the valley and lake of Geneva. The Alps must therefore have subsided while Jura remained stationary; and thus destroyed the slope from the top of the Alps to the top of Jura; or, Geneva had been a primary and volcanic mountain which has now subsided. Blocks of granite have been found on the southern shores of the Baltic, and even in England, where no parent rock is nearer than the northern side of the Baltic. Our inference is, that the North Sea and the Baltic have been the stations of primary mountains, whose summits formed a regular inclined plane to the places where these blocks are now found. We might multiply examples in England, especially about Warwickshire, and southward, of blocks both of primary and secondary formations resting on the summits of hills. What force of water could carry them to the tops of these hills and then leave them there? But it might strew them over a plain, and assist in scooping out valleys in that plain, when the remaining parts would become hills, with these blocks upon them.

Lastly, as the earth, during the time that these formations were going on, must have had a much higher temperature than at present, we may expect that the organic remains found blended therewith, will more resemble those of our present torrid zone than of the temperate or colder regions, which we actually find to be the case. And we are not destitute of proof that the earth still retains a heated nucleus, since the temperature of mines invariably increases as the depth increases, the regular scale is one degree for every 150 feet. The temperature of Dulcoath mine, 1380 feet below the surface, is 75·5 deg.

4. PRIMARY ROCKS.

"WITH the exception of granite," says Dr Macculloch, "it is not probable that geologists have yet discovered a rock beneath which organic remains may not be found.—Their gra-

dual disappearance, in those cases where the secondary lime stone assumes the massive structure and crystalline texture, will illustrate this opinion; and suggest the possibility, that even the common primary limestones may originally have contained organic bodies." It is evident, therefore, how very little foundation there is for considering any rocks *primitive*, since it appears that we are acquainted with no rock or part of the earth's surface which has not been completely re-arranged since the existence of aquatic animals and vegetables on the surface of our planet. The term *primary*, therefore, relates only to rocks of posterior formation, and not to the creation of the world. The lowest rocks with which we are acquainted are those that have been the most completely dissolved in the great revolutions, to which the earth's surface has been subject; they are consequently the most perfectly crystallized, and contain the fewest traces of organic remains,

Granite is not only the chief of the primary rocks, but possesses strong claims to its being considered the Parent of all rocks. It is decidedly of *igneous* formation, and is always the central or conical mass of its own ridge or suit of rocks, with gneis, mica-slate, &c. wrapped round it in mantle-shaped, conformable strata. It has every appearance of having been thrown together, or exuded from the earth in a fluid state, in the first of those subsidences that have any vestiges remaining; for, besides the larger masses, it is found in veins in some of the other primary rocks; these veins, like all others, have always been filled by injection from beneath and never from above. They are of various ages and distinctions, and the more recent ones graduate into those of the trap or basaltic family. Granite is therefore the lowest rock with which we are acquainted, for beneath it man has never penetrated; yet the sources of volcanoes, and of metallic veins, and perhaps Whin-dykes, seem to be far below it; as well as the origin of all the hot-springs.

The three component materials of granite are quartz, feldspar and mica, which are in grains or apparently fragmented crystals, cemented together with a crystalline bed of feldspar. Their proportions vary greatly in different rocks, and often in specimens from the same rock; but feldspar in general greatly predominates. However the feldspar or mica is often displaced by some other material, as hornblende, chlorite, and even limestone. This circumstance has given rise to great contentions

among geologists about words, viz. whether these latter rocks should be called granites or have other appellations. The oldest granites have the largest crystals of feldspar interspersed, and others cannot well be distinguished from sandstone. The colour also greatly varies; that of some being nearly a flesh red, by reason of the feldspar containing a large portion of the red oxide of iron: such granites, on account of the affinity which this oxide has for water, are much less durable than those wherein the feldspar is nearly white. The mica also greatly varies in colour in different granites. Granite is not stratified; but is generally separated into large vertical blocks, which have a tendency to assume the rhomboidal form. Its natural structure seems to be globular, for the most perfect specimens are generally in globular masses composed of concentric, radiated layers of different degrees of compactness around a harder nucleus. These masses are occasionally two or three yards in diameter, and are often detached from the main rock, or imbedded in a softer kind. The globules never shoot into each other, but where they come in contact, the layers are wanting;—so that the whole mass of the rock is thus in coats: the same structure may be found in all rocks of igneous formation.

Gneis is a kind of slaty granite generally in the declivity of granitic mountains. The three constituents are disposed over each other in layers. It contains less feldspar than granite, and the feldspar, is generally white, grey, or a yellowish white:—the mica is mostly black. But granite frequently graduates imperceptibly into gneis. It constitutes a principal part of the rock formations in Sweden, and abounds in the Western Isles of Scotland; it is also found in Ireland, but seldom occurs in England.

Mica-slate or Schistose, is composed of quartz and mica, graduating *below* into the gneis on which it rests, and *above* into the superincumbent clay-slate. Its colour is generally a light grey, sometimes inclining to green or yellow; the finer kinds have a pearly lustre. It frequently contains scattered crystals of garnet, which occasionally constitute a considerable part of the mass of the rock; and sometimes crystals of other minerals; also thin beds of crystalline limestone, serpentine, and seams of quartz;—indeed it often appears to take the form of common sandstone mixed with mica. In some situations neither gneis

nor mica-slate is found between granite and the next class of rocks.

Crystalline Limestone. This rock consists of almost pure carbonate of lime; though the white kinds, called *statuary marble*, sometimes contain a considerable quantity of silica. There are many varieties as to colour:—some being yellow, others greenish or inclining to red. The less pure kinds have a mixture of mica, which occasions them to have a stratified appearance. It is chiefly imported from Italy, Switzerland, and the Grecian Archipelago, in all which places it composes entire mountains. A white kind occurs in the Isle of Skye; and many rocks of it intermixed with mica slate and serpentine are found in different parts of Scotland, and the adjoining isles; but this primary marble has no where been found either in England or Wales. It sometimes alternates with granite, or gneis and mica slate; in Canada, and even among the Alps, it is found supplying the place of feldspar in granite.

Hornblende is a constituent part of many rocks, and seems to be the connective link between the above rocks and what are to follow. In short, it usurps the place of the mica, of which mineral it forms a variation, by having in its composition a much larger portion of magnesia with some lime, and a deficiency or total absence of potas and manganese. Hornblende is, therefore, the almost sole ingredient of a great variety of rocks. It sometimes occurs in beds of gneis, when it takes the name of *primitive trap;* it has, occasionally a slaty structure, and is then called *hornblende-slate.* When intermixed with crystals it is called *greenstone*, of which there are entire mountains; but in this case, as perhaps in all, it is more properly classed with the trap formations, which for the most part consist of hornblende, feldspar, and augite. The colour of hornblende is black or dark-green. Its specific gravity is greater than that of feldspar or quartz; but it is less hard, and may be easily scratched with a knife. It yields a bitter smell when breathed upon, and easily melts into a kind of black glass.

Serpentine. The colours of this beautiful mineral consist, for the most part, of various shades of light and dark green spots or clouds intermixed, bearing some resemblance to the variegated spots and colours of a serpent's skin, whence its name: though some varieties of it are red. It is chiefly constituted by feldspar and a substance called *resplendent* hornblende; but the crystals are often so small as to give the rock a uniform

appearance; it is also abundantly intersected by veins of steatite. When serpentine is found intermixed with patches of crystalline white marble, it is called *verde-antique* which ishighly valued in ornamental sculpture. A softer kind of serpentine is called *lapis ollaris* or pot-stone, possessing the power of resisting the action of fire. It is used in some parts of Switzerland, Germany, and in Upper Egypt as a substitute for pans in common culinary operations. Some varieties are translucent; others are nearly crystallized, forming Schiller's spar; and many species are found blended with talc and hornblende. Serpentine has not been observed in the northern parts of Asia, nor among those parts of the Andes examined by Humboldt, but it is found in many of the mountains in Europe. It forms the upper part of Mont Rosa the highest mountain in Switzerland. Among the Alps it is generally found on that part of the mountain facing Italy and Genoa. The only place where it seems to have been discovered in England, except a species perhaps in Charnwood Forest, is in the Lizard Point. It occurs in Radnor, and there are beautiful varieties in the Isle of Anglesea. In Upper Egypt are whole mountains of serpentine.

These are the principal of the primary rocks, but there are some others with several varieties. They seem all nearly allied to each other, being composed of varying quantities of the same materials, which are all found in granite. Certain of the primary class consist almost of the same material, as crystalline limestone. There are several mountain ranges of quartz rock: in South America is one 9,500 feet thick. At Sleat, in the isle of Skye, a bed of shell-limestone is included between two beds of quartz rock. There are also mountains of feldspar; and in the Crimea, are ranges principally composed of mica of the most beautiful gold colour. In the Oural chain is a range of quartz, another of feldspar and a third of talc. On the eastern side of Siberia is one of jasper.

Whether any of the granite formations are posterior to the other primary rocks, had long been a source of contention among geologists till Dr. Macculloch set the question at rest. "All the varieties of gneis" says he "are occasionally intersected by granite veins, and they are indeed almost characteristic of this rock, being rarely absent for any considerable space and seldom traversing micaceous schist unless under circumstances where they can be traced to some neighbouring mass of granite. They are however most abundant in the

granitic division. They are infinitely various in size, and in the number and intricacy of their ramifications; and it is further worthy of remark, that the contortions in any mass of gneis are always proportioned to the number and importance of those which it contains. Hence it is, that the schistose is more free from contortions than the granite variety. It is nevertheless proper to make an exception respecting those beds of gneis which alternate with other rocks, such as clay slate, these, as far as I have observed never contain veins. In some varieties of gneis they are so abundant as nearly to exclude the original rock, so that the mass presents little else than a congeries of veins.—If the intricacy of ramifications, and the intersection of one set of veins by a second and third of different textures, present an argument in favour of a succession of these at several periods, there is here no want of such evidence." He also describes granite veins as traversing both gneis and mica slate or schist, in the islands of Tirey, Scalpa, and Coll.

5. TRANSITION ROCKS.

THE principal distinction between this class and the primaries, is, the less perfect crystallization, and the presence of organic remains,—viz. corals, encrinites, and testacea; and a few vegetable impressions of the monocotyledon class of plants. They have been called *transition* from the supposition of their having been formed after the primaries had been sometime fixed, and while the earth was passing into a habitable state; however this idea is now abandoned, so that transition must be considered as a name without meaning. They have also been called *intermediate*, which is a less objectionable term, from their position between the primaries and all those that are to follow, which were once included under the general term *secondary*.

Clay-slate, argillaceous-schistose, roofing-slate, or killas (a provincial term in Cornwall for this rock and its varieties) is considered as forming the connective link with the primaries. Its lowest strata often graduate into mica-slate, and always have a similarity of appearance with that rock; while its upper strata contain organic remains. Its colours are various shades of grey, inclining to blue, green, purple and red. By the presence of a large quantity of silex it graduates into *flinty-slate*; and by the presence of magnesia it becomes *talcous* and *chlorite-*

slate. *Drawing-slate* is another variety, containing carbon. The Yorkshire slate contains cubic crystals of pyrites, and is sometimes covered with configurations of this substance resembling trees. Many of this class or varieties alternate with or graduate into each other, as in Charnwood Forest and North Wales. In the Western Isles they alternate with greywacke and gneis

Greywacke is a variety of flinty slate, containing imbedded grains or fragments of other minerals. The finer kinds, which are merely the coarse clay slate, are called *greywacke-slate*:—some, by a superabundance of mica, pass into mica-slate, The fragments of clay-slate, mica-slate, and flinty-slate are so large in the coarser kinds of greywacke, as to give it the appearance of a breccias or pudding stone. Greywacke alternates with vast beds of flinty-slate, trap and transition limestone.

Old Red Sandstone. Greywacke passes into this formation, which is a coarse grained sandstone, apparently constituted of abraded quartz, feldspar, and mica, with occasional fragments of most of the above mentioned rocks cemented in a crystalline bed of silex. Its prevailing colour is a dirty iron red or dark brown, but it is sometimes grey. It occasionally contains beds of limestone, and lime sometimes enters into its composition, when it takes the name of *cornstone*. It constitutes the basis of the Pennine Rocks, or of all the coalfields; but frequently rises into mountains of two or three thousand, and in Scotland of between three and four thousand feet in height. It is no where found in the north of England, except at the foot of Cross Fell (in its most usual form of a coarse pudding stone) extending from near Melmerby to near Murton about 15 miles: but it forms a large district in the south and south-west corner of Wales, with extensive tracts in North Wales, Anglesea and a great deal of the northernmost counties of Scotland. Its thickness in the Forest of Dean, where it is interposed between the carboniferous and transition limestones, exceeds 2000 feet; and in Herefordshire and Brecon it is supposed to be still thicker; while in some parts of Glocestershire, it is not above 2 or 300 feet. In Somersetshire it forms the most elevated summits of the Mendip hills.

While some geologists reject the old-red-sandstone, not only from the primary and transition, and place it among the secondary, Dr. Macculloch vindicates its undoubted claim to an honourable station among the primaries, for he found it alter-

nating with gneis. It is a regularly statified rock where it retains its nearly horizontal position, but where its strata are almost vertical, that is, where it has been most affected by the subsidences, its stratification nearly disappears; and it therefore assumes the aspect of granite, or rather the irregular gneis with which it is accompanied. In some places this transition is effected by schist, grey, indurated sandstone and *quartz-rock.* That it once formed the bottom of the ocean, as we have already conjectured, appears from these instances where its strata are least disturbed; viz. the surfaces of the flags bear the same marks of undulation, which are so frequently seen in the secondary sandstones, and which resemble so much the marks left by the sea on sandy shores.

Humboldt, who has examined the most distant mountain ranges, and has perhaps made more observations than any other geologist on primary and transition districts, proves, that the rocks which belong to the same epoch of formation are the same in all quarters of the world. In his late treatise on "The Superposition of Rocks," he states the disposition of the primary and transition to be as follows. I. Primitive granite. Primitive granite and gneis. Stanniferous granite. Weistein (whitestone or eurite) with serpentine. II. Primitive gneis. The following are parallel with each other:—gneis and mica-slate; granite posterior to gneis but anterior to primitive mica-slate; primitive syenite; serpentine; and limestone. III. Primitive mica-slate. Granite posterior to mica-slate but anterior to clay-slate. Gneis posterior to mica-slate. Greenstone-slate. IV. Primitive clay-slate. The following are parallel to each other and sometimes to the primitive clay-slate: quartz rock (with specular iron). Granite and gneis posterior to clay-slate; primitive porphyry; primitive euphotide posterior to clay-slate. *Transition:* I. Granular talcose limestone; transition mica-slate; greywacke with anthracite. II. Transition porphyries and syenites immediately covering primitive rocks; black limestone; and greenstone. III. Transition clay-slate, containing greywacke, greenstone, black limestone, syenite and porphyry. IV. and V. Porphyries; syenites; and greenstone, posterior to transition clay-slate sometimes even to limestone with orthoceratites. VI. Transition euphotide, (a serpentine).

If this statement of Humboldt and those cited from Dr. Macculloch be correct, it is evident that the primary and transition rocks owe their birth to a number of subsidences rapidly suc-

ceeding each other: the later ones to a certain degree (as they occurred either partly or altogether in the same area) deleting the former. Now the first of these might not perhaps be on the most extensive scale, but as the earth then contained the most heat, the edges of the subsidences would be the most extensively fused. Supposing the edge of a subsidence to be beneath the sea, and a vast quantity of fused matter to be exalted by a distant depression: may we not suppose that this mass would be too extensive for the water to remove; or, that the central part would be solidified, before the sea could bear it away; hence it might be left in conical peaks with all the marks of aqueous attrition around it. In some cases, viz. where there was little or no water, the mass would form beds of granite; and where there was a great depth of water around the mass, or sloping down its sides the greatest quantity of matter would be deposited, forming those mantle-shaped strata of gneis and mica-slate, which so frequently invest the declivities of granite mountains; and above these, or at a greater distance, would the clay-slate be deposited; next, the organic remains of the disturbed ocean; and afterwards, vegetable substances, when the retiring ocean had swept over subsiding continents.

The following experiments are adduced as illustrative of this process. Quartz, feldspar, and mica were finely pulverized, and blended in a tall vessel filled with water; whence, the water being gently agitated with a hair rope, the ingredients were deposited in the formation of gneis graduating into mica-slate. Feldspar, having the greatest specific gravity, was at the bottom, then quartz, and the chief of the mica was at the top. Again; with pulverized mica-slate was mixed a blue-clay reduced to a fine powder by burning, when mica-slate and clay-slate were the result: hence the clay-slate contains more organic remains, which would be the last deposited, and they are the most abundant in the upper strata. With water saturated with salt the results were more decisive. From these experiments we may conclude, that throughout all the other formations, different series of rocks may have resulted from the products of one and the same subsidence.

Suppose a reiteration of such subsidences to intersect the formations caused by the former, solving these new mountains by heat under pressure, we may then perhaps arrive at some idea how materials deposited from water might attain a crystalline stucture; for crystalline limestone has been formed artifici-

ally from chalk by heat under pressure. And as the materials of granite were thus solved and suspended in water, the ingredients according to their affinity for water would be variously separated: hence the feldspar of gneis is destitute of the oxide of iron, and feldspar otherwise exists in less proportion, much of its aluminous part being suspended till the mica-slate was deposited, and then it formed the clay-slate. The oxide of iron would also be somewhere deposited, and other materials would be also separated or variously precipitated. Now when these new formations were afterwards fused by heat, and their materials were again subject to the above process, we should have a different order of rocks. Hence originated the vast variety of rocks that compose the earth's shell, and the wild confusion that prevails in the primitive districts. At the same time we see but little foundation for the distinction of primary and transition as applied to rocks: only, let it be remarked, that generally the igneous productions of the primaries are chiefly granites, while in the transition they are mostly serpentine, syenite, and porphyry;—but subsidences posterior to all those we have hitherto mentioned have taken place and affected these formations; hence originated metallic veins and the trap or basaltic rocks.

As all the materials of stratified rocks were once suspended in the waters of the ocean and thence deposited, we must expect that the *tides* would have a considerable influence on such depositions; consequently we find the direction of the strata of all the formations, in northern latitude, generally ranging from N. E. to S. W. Humboldt, from many observations both in Europe and America, deduces an angle of 50 degrees with the meridian: the natural direction of the tide being about at this angle from N. E. to S. W. Hence as stated Sec. 2, when mountains range from N. to S. the eastern declivity is a slope, and the western is precipitous; but when they range from E. to W. the south is precipitous and the north is a slope though in a less degree than in the former case; but it is evident, that in most cases they must be greatly modified by circumstances. On the same principle the shores of the Red Sea are at a higher elevation than the eastern shores of the Mediterranean; and the Atlantic, on the eastern side of America, is at a higher level than the Pacific on the western side.

6. PENNINE CHAIN.

Or the Carboniferous or Mountain Limestone, and, Millstone Grit and Shale.

THIS series differs as little from the transition as the transition do from the primaries. Indeed the transition and mountain limestone so nearly agree that we deemed it useless to describe them apart; for it often requires much consideration to distinguish them, so gradual is the increase of crystallization. They rest on the old-red-sandstone; but the mountain limestone, the lowest of this series, is sometimes separated from that rock by a thick shale resembling that of the millstone grit.

Carboniferous, metalliferous, entrochal, encrinal, shell, or *mountain* limestone. The first of these appellations is derived from its being associated with the "great coal formations;" the second from its mineral riches, the lead-mines of Northumberland, Durham, Yorkshire, Derbyshire, and Somersetshire, as well as many copper-mines, being in it; the third, fourth, and fifth from its organic remains; and the last from its usually forming considerable hills, some of which are more than 1000 feet above the sea-level. It has sometimes been called *cavernous* limestone; for with a few trifling exceptions, all the British caverns are in it.

"The texture of this rock is generally imperfectly crystalline, and sufficiently close and hard to afford marbles of a durable polish. Its prevailing colour is grey, passing on the one hand, into greyish white and yellow; and on the other, into greyish blue and black; occasionally also, a red shade of colour may be observed. Its purest beds appear to contain 96 per cent. of calcareous matter; but by the admixture of other ingredients, it often passes into magnesian limestone, ferruginous limestone, bituminous limestone, and fetid limestone. It usually presents beds of very considerable thickness; a continuous series of which often extends many hundred feet in depth without the intervention of any other rock, the strata being divided by only thin partings of clay; but sometimes this series exhibits alternations of various heterogeneous rocks, particularly toadstone, grit and shale; so that the proportion of the limestone beds in constituting the series of strata here denominated from them, as its characteristic feature, varies; they being sometimes exclusively prevalent: and sometimes forming little more than one

third of the whole series; occasionally also the limestone beds themselves become more thinly laminated." The thickness of the whole series is various, but in some instances it exceeds 900 feet.

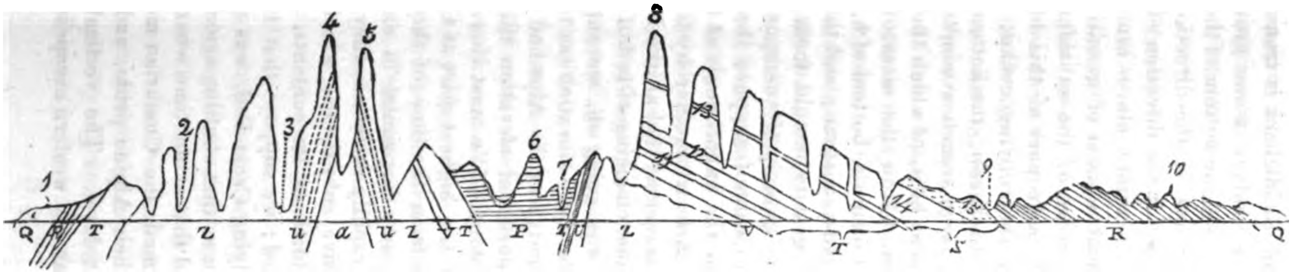
Millstone-grit and Shale. The above limestone formation is generally overlaid by a series of sandstone and slate-clay beds, with occasionally beds of limestone and strata of coal. The sandstone beds commonly called the millstone grit, chiefly consist of coarse quartzose particles of various sizes agglutinated by an argillaceous cement. It has every appearance of a rock mechanically formed from the detritus of preexisting materials, and rounded particles of feldspar may be occasionally found in it. It is often seen under the form of a *pudding* stone, but it sometimes assumes a finer texture, when its mechanical structure almost disappears. The shale beds differ little from those of the coal measures. They sometimes contain nodules of clay iron-stone, and martial pyrites abound in them. The variety of calcareous spar, called *satin spar,* appears to belong to them, and they often abound in bitumen. The limestone differs from the mountain limestone in being black, or in containing more bitumen, and more perfect organic remains. It also affords a beautiful black marble; the finest specimens of which are found near Ecton copper mine, which is in this formation. The coal beds are few in number, very thin, and the coal is of inferior quality. The thickness of the whole series is sometimes between 7 and 800 feet, and where it forms the summits of mountains, it is occasionally between 2 and 3000 feet above the level of the sea; Cross Fell is the most elevated point, and its summit is 2901 feet above the sea level.

The series of rocks described in this section form that range of mountains now denominated the *Pennine Chain.* It extends from the Cheviot (*transition*) on the north, to the Trent on the south, including Cross Fell, the western moorlands of Durham and Yorkshire; between Stainmore and Ingleborough it abuts against the lake mountains, (*transition* and *primary*) of Cumberland; it afterwards forms the boundary between Lancasshire and York, including Pendle hill, and Blackstone edge; thence it stretches to the Peak of Derbyshire, and is finally lost in the banks of the Trent.

Our Theory of the Earth, is, that the primary, transition, Pennine chain, the coal formations, and lastly the new-red-

sandstone, including their subordinates, together with the metallic veins, and trap or basaltic formations were all the result of a series of rapidly succeeding subsidences or concentrations of different portions of the earth's surface, chiefly occasioned by the contraction of the terrestrial mass from the loss of heat. The primaries we, therefore, consider as the only visible remains of the first of these subsidences, some of them remaining as they were left solved by heat; others were deposited from water, and afterwards crystallized by their own attraction of cohesion, assisted by moisture, heat and electricity; the transition were partly the result of later subsidences, but they chiefly originated from the diluvium of the primaries, deposited at a greater distance from the scene of volcanic action, and consequently they were less subject to the effects of heat than the primary, and are therefore less crystalline; while the Pennine rocks, which contain a great deal of the oxide of iron in the shale and slate-clay, were still more distantly, both with respect to time and space, deposited: but in different places these formations have been broken through, and converted both into primary and transition by the presence of heat, while in other places, where there was less heat, the strata are merely bent, crumpled, broken, or contain immense caverns.

The following Cut is a vertical section, taken across that part of the island where all the rocks of the first æra of organic remains are developed.



1. Whitehaven. 2. Loweswater Lake. 3. Bassenthwaite Lake. 4. Skiddaw, 3022 feet above the sea-level. 5. Saddleback, 2787 feet. 6. Penrith Beacon. 7. River Eden. 8. Cross Fell, 2901 feet. 9. Wolsingham. 10. Durham. 11. Melmerby Scar Limestone. 12. Whinsill. 13. Great Limestone. 14. Limestone shale. 15. Milstone grit. Q. Magnesian limestone. R. Coal measures. T. Mountain limestone. Z. Slate. u. Slate, Greenstone, Hypersthene, and Syenite. U. Greenstone, broken Coal and Limestone. a. Granite. V. Old-red-sandstone. P. New-red-sandstone. The horizontal line is the sea-level.

The slate of Skiddaw and Saddleback is transition, so that we have the primitive and secondary in one group. Now we suppose this slate to have formed the bottom of the ocean, when two subsidences took place; one in the direction of the great European basin, and the other in the direction of the Atlantic ocean. The earth's shell therefore clave asunder between Skiddaw and Saddleback, and a mass of granitic matter was exuded by the unequal pressure of the subsidence upon the earth's heated nucleus. A large part of this effused granite would be carried away by the retiring ocean; also, as the material of the slate, hitherto forming the bottom of the ocean would not be agglutinated, large trenches would be excavated in it, leaving insulated peaks or hills, of which the above mountains are perhaps instances. Now the mass of matter thus swept off by the flood would form the bottom of a new ocean,—might first deposit the old-red-sandstone; and then the shells, which, having less specific gravity, would form the mountain limestone, that appears to be principally composed of comminuted shells. However, we cannot suppose that these would be regularly deposited as in the experiments at the end of the last section, but would be thrown together by the rush of the mighty ocean in immense masses: so that all the Pennine rocks might possibly result from one changing of bed of the ocean.

While the above process was going on, we suppose that the Cumbrian mountains had the same elevation (as taken from the earth's central point of gravity) as the Alps had or have; and that they retained this proportional elevation till after the formation of the new-red-sandstone. We must therefore consider the strata as displayed in the highest part of Cross Fell, as remaining nearly stationary from the time of their deposition, and as being originally nearly horizontal in each direction. But as they now dip very rapidly eastward, they received this inclination, by the successive subsidences which formed the basin of Europe and gave birth to its contents. To trace the strata of Cross Fell westward; we suppose that the stratum of old-red-sandstone V underlying Cross Fell, was a continuation of one and the same stratum as that abutting against the slate Z eastward of Saddleback, and that at the time when the Atlantic Ocean was principally formed, the Cumbrian mountains were despoiled of the chief of their Alpine pride, and were finally depressed to their present level. The vertical and broken strata of coal, &c. T U near the western escapement of Cross

Fell, are indications of a vast *slip* which has here taken place. After such a depression as this, what were before sections of the trunks of rivers or valleys would be converted into lakes, and, of course, new rivers would be formed.

What may be called the internal evidence of our theory, is, the inclination of strata. Though strata may be formed almost *vertical* down the sides of a volcanic mountain; yet, according to every theory all those in the above *cut* must have been formed nearly horizontal, even those of the greenstone and syenite *s s* on each side of the granite were probably so formed, though they here appear nearly vertical. However the vertical appearance in the above section is a great deal magnified, for the altitude is taken from a scale of about 26 times greater than the length. Between the tops of Skiddaw and Saddleback must be not less than 4 miles. Were this cut therefore magnified in length 26 times, the inclination would not be so abrupt. Nevertheless there are many places on the earth's surface, where the strata, though originally perhaps horizontal, are now perpendicular. Indeed horizontal strata, except some pieces of table land, are very rarely met with in formations older than the coal measures. The strata, both of the primary, transition, and Pennine rocks are broken, crumpled, contorted, and arched in every possible direction. The rents are often deleted in the first, by the fusion of the materials; while the fusion in some places of the transition, and occasionally in the Pennine rocks, has only been to make the rock pliant like a piece of leather; hence a variety of saddle-backed, arched-like ridges, and caverns. But where the rock was not so pliant we have extensive caverns, in some places engulfing rivers, and in others throwing them out in immense floods in the form of springs. The Mendip hills, which are of the Pennine rocks, are remarkable instances of contorted and disturbed strata.

7. METALLIC VEINS.

THOUGH the metallic veins are sometimes found in the coal measures, and even strings of galena extend into the magnesian limestone, yet, as their chief seat is in the primary, transition, and lower strata of the Pennine chain, they seem to claim a consideration in the present place.

The specific gravity of granite, and the other rocks composing the earth's shell is only about $2\frac{1}{2}$, while that of the whole earth

has been calculated to be above 5:—from this circumstance and the peculiar structure of metallic veins, we have reason to conclude that the internal part of the earth chiefly consists of metallic oxides. Metallic veins are vast clefts or fissures, often vertical, traversing rocks and even mountain ranges. They are of various width from many yards to a mere thread. These clefts are always filled with a material differing from the rock in which they exist. The metal is sometimes in a native or pure state, and sometimes it is in ores. In the former case, it is generally accompanied (for native metal or even ore rarely if ever completely fills the fissure) by calcareous spar, fluor spar, ponderous spar, and quartz, with which the metallic substance is generally confusedly mixed, but they are often found separate. The veins are sometimes separated from the rock by a thin wall or lining on each side, composed of some mineral substance; and at other times by a layer of clay; and these are also frequently mixed with the metal or alternate with it in layers, or the metal is found in it in globular masses. It is called the matrix, vein-stone, or gangue.

The thickness of veins and the quantity and quality of the ore vary in every mine; and these variations often occur in the same vein. Sometimes the metal has expanded laterally into the crevices or caverns of the containing rock. The veins occasionally degenerate into mere dykes filled with clay or rubbish, or merely empty fissures, the sides of the rock being in contact; and at other times the cleft contains spar, as in the fluor spar mine near Castleton. The crystallizations in this mine are supposed to equal those of the famous grotto of Antiparos.

One vein often cuts through and displaces another, shewing that they have been formed at different times. And sometimes a number of veins intersect each other at a point, where a very large mass of metal is found. Among the Andes a vein of silver has been traced 90 miles; its width is 9 feet, it is straight and uniform in its course; and sends off smaller branches, which have been pursued, till they penetrate the mountain, 30 miles.

Some veins contain different metals ranged in vertical strata. One instance of which may give the reader some idea of the whole. It is the vein Gregorius at Freyburg, and is composed of nine layers vertically arranged as follows.

GNEIS ROCK.	Quartz.	Galena.	Brown Spar.	Silver Ore.	Calcareous Spar.	Silver Ore.	Brown Spar.	Galena.	Quartz.	GNEIS ROCK.

Another in the same neighbourhood has thirteen strata on each side of the central calcareous spar. Other veins contain different metals at various depths. In some of the mines of Saxony ores of iron, copper, cobalt, and silver succeed each other. In Cornwall tin or zinc is frequently succeeded by copper. Mines are seldom rich near the surface, but grow more valuable as they descend for a certain way, and then become less so: though in general the miner is stopped in his descent by water. However, all experienced miners concur in the remark, that veins are widest at top, and regularly contract as they descend.

The veins in *hard granite* seldom afford much useful metal, but the softer kinds contain tin, lead, iron, zinc, bismuth, and cobalt; and in *gneis* are found silver, copper, lead, tin, and zinc. In *mica-slate*, occur, copper, tin, lead, and antimony: *clay-slate* contains silver, copper, lead, zinc: *hornblende-slate* copper. *Limestone* contains copper, lead, and zinc, antimony, and iron:--some of these veins, especially of lead and zinc, extend a considerable way into the *millstone-grit;* and even in the *coal-strata* have been found native, galena, and manganese—with abundance of iron in the *shale*. The gold found in Scotland was procured from Leadhills, which are mostly composed of coarse slate (greywacke?) *Syenite* and *granular marble* are not often metalliferous, yet gold and silver, as well as lead and zinc are sometimes found in *syenite, porphyry*, and in the *old-red-sandstone*. The last two metals have also been found in *serpentine;* and gold is frequently met with in the craters of old volcanoes, or is ejected with the lava. When *greywacke* is in large masses, and consists of few fragments, it sometimes contains gold and silver, also antimony, lead, and iron. Mercury is found in clay-slate, limestone, and slate-clay of the coal strata—see Chap. XIII. Metallic veins, when exposed to the atmosphere, present various appearances. Iron, and very often tin are exhibited in the form of a brown powder, lead, of a pale yellow powder; and copper, a green one. Fluor spar,

found at the surface of a vein, generally indicates that metal of some kind is beneath.

The bases of all rocks are metallic, so that every rock or stone may, in one sense, be called a metallic ore. But such rocks or stones as have only the metalloids for their bases are chiefly distinguished by their want of specific gravity, which seldom exceeds 2½; while the specific gravity of the ores which contain the metals is generally above 6. For this reason in our Theory of the formation of the Earth, we suppose the metals to have been originally buried beneath a thick shell of metalloid rocks; how they became otherwise we proceed to explain.

If we consider a number of such subsidences at the opposite side of the globe as finally gave birth to the great hollows or indentations that contain the Pacific and Atlantic oceans, we shall have no difficulty in conceiving that around the edges of the subsiding areas would be exuded or elevated vast quantities of matter from beneath the depressed part, especially as we consider the earth to contain a fluid nucleus; and these elevations or emissions would be attended with all the appaling phenomena of earthquakes and volcanoes. In this manner it is easy to conceive how the Andes received their towering height, and became the depositories of the greatest mass of metallic ores hitherto discovered. And however the metals may exist in the earth's nucleus, it is evident that they would, in this case, undergo a process similar to that of smelting, and the metal would be blended with the fused materials of the earth's shell. This will account for the formation of some veins, and the overlying masses of metallic ores, but there are many veins, indeed perhaps the chief of them, that it does not agree with. As we suppose a great many subsidences took place, not only after the primary and transition but after a great many of the secondary rocks were formed, the earth's shell would be solidified to a great depth; may we not suppose, then, that the shell would often be split down to the heated nucleus when no ejection of fluid matter would take place, by reason of the chink being too narrow, while at the same time the metals in an aeriform state, being more subtile, might escape; and coming towards the colder surface of the earth would be condensed and deposited in crystalline ores, along with other crystalline substances. Different subsidences would therefore go to greater depths in the nucleus, and perhaps reach the beds of other metals, so that a vein may contain a variety of metals: but

supposing different metals sublimed at the same time, it is conjectured that they would crystallize separately. But there are who suppose, that nature, in these hidden mines, elaborates different metals from the same material. What are called *slickenside*, (being a kind of vitrification on each side of the con taining rock) seem to be in favour of these veins, being a kind of vent-holes from the internal parts of the earth, for a vapour highly charged with the electric fluids; and if so, perhaps the ores in some veins may be even now increasing.

8. TRAP OR BASALTIC ROCKS.

TRAP is now used in a generic sense, and comprehends a variety of rocks, viz. syenite, porphyry, basalt, greenstone, claystone, clinkstone, whinstone, and toadstone. It is chiefly in dykes and large veins, that intersect all formations from the granitic to below the chalk series. But it often occurs in vast overlying masses, which in some places are said to be stratified; however the stratification does not seem to be anywhere complete, and with this slight exception it is decisively *igneous;* being a continuation of the granites from which it chiefly differs by containing less quartz, and hornblende instead of mica; it also contains soda, while the alkali of granite is potas. The trap rocks are all so nearly allied, that they pass, in many cases, into each other, and very often into the rocks with which they are associated.

Syenite. Primitive syenite seems to be granite with hornblende instead of mica, but the secondary consists of feldspar and hornblende. The feldspar is generally red, and the hornblende black or dark-green; when the latter predominates and its crystals are small, it is called *greenstone.* It occurs in Charnwood forest, in the Malvern Chain, in Cornwall, Wales, and Cumberland. In the Isle of Skye, greenstone, amygdaloidal claystone, common pale syenite, micaceous syenite, and simple blue claystone are found in irregular alternations; in some places, by the addition of a little quartz, it assumes the character of porphyry; and in others, by a slight mixture of mica it presents a granitic appearance. It abounds in Upper Egypt or Syene, whence its name.

Porphyry. By porphyritic rocks is generally understood a rock with a compact crystalline cement, in which very small crystals are imbedded, so that it generally requires another

term to make it appropriate. Thus, hornstone porphyry, claystone porphyry, pitchstone, and obsidian porphyry. The base is nearly allied to trap, and its crystals are generally quartz and feldspar. Porphyritic rocks occur in the neighbourhood of volcanoes. Chimboraco, the highest of the Andes, rises 21,440 feet above the sea-level; the primary rocks only reach half the height, the rest is an immense pile of volcanic matter; so that granite, gneis, &c., and then porphyry, and basalt with other volcanic products succeed each other, "arranged in the form of regular and immense columns, which strike the eye of the traveller like the ruins of enormous castles lifted into the sky." It is found in most places along with syenite.

Basalt and *Whinstone.* Syenite, porphyry, and basalt have frequently a columnar structure, and form mountainous ranges of columns of imposing grandeur similar to granite. The globular structure, as in granite, also prevails in those rocks, and gives the horizontal sections of the columns the ball and socket-like form, so much dilated on by travellers who have viewed the Giant's Causeway. When melted basalt or lava is cooled rapidly, it forms a glassy substance; if cooled slowly, it has a stony texture; but if very gradually, it rends into the prismatic or columnar form. "The most usual character of the basaltic rocks in England, are, an iron grey colour approaching to black; a considerable tenacity and hardness, a sharp and sometimes a conchoidal fracture, a granular aspect often reflecting light from a number of brilliant spots or striæ, some of which seem to be feldspar, others hornblende or augite; very liable to superficial decomposition, in which case, the colour passes from the further oxydation of the contained iron, to a rusty brown, often mingled with spots of green arising apparently from the grains of hornblende."

In Avergne, in France, is a remarkable range of about 60 volcanic mountains chiefly consisting of basalt, but accompanied with blocks of granite, and transition slate exhibiting the action of fire. This scene of antediluvian volcanoes extends over an area of several thousand square miles. But the most remarkable range of this kind is that in which the famous "Giant's Causeway" is situated in the north-east point of Ireland. This extensive formation of basaltic rocks is supposed to have existed nearly in the same parallel of longitude, from the Canary and Madeira Isles, to Ireland and Scotland, the Hebrides and Iceland:—the volcanoes of the northern and southern extremities

being still in an active state. The *Giant's Causeway* comprises two principal promontories eight miles apart, consisting of various ranges of pillars and strata, which rise perpendicularly from the sea to an elevation of 500 feet. Such is the regularity of the columns, that they seem to vie with works of art; and such the grandeur and magnificence of the scene, that every one while viewing it, seems lost in wonder. Another scene of the same kind is presented in the isle of Staffa one of the Hebrides.

What are called *Whindykes* belong to this series of rocks. They are clefts in the solid rocks filled with basaltic materials, and extend many miles across a country, splitting some rocks, while they are overlaid by others, and generally depressing the strata or forming a slip on one side. The most interesting one in a geological point of view, is, perhaps the one called *Cockfield* or *Cleveland Dyke*:—because it is evidently posterior in formation to the oolitic series of rocks through which it ranges. It is supposed to extend eastward to the German Ocean. It passes seven miles southward of Whitby, leaves the oolitic range on the southern side of Roseberry Topping, crosses the Tees two or three miles to the south of Stockton, passes at about the same distance to the northward of Darlington, (though it is no where visible in the magnesian limestone formation which it here enters,) forms the high ridge of Bolam, three or four miles southward of Bishop's Auckland; at Cockfield Fell, it comes in contact with the coal strata, which, on the north side, are depressed 11 feet. The *low main* coal contiguous to the basalt is only 9 in. thick, but at the distance of 50 yds. from it enlarges to 6 feet. The coal is reduced to a cinder, and the sulphur is sublimed from the pyrites near to the dyke. From Cockfield Fell it is supposed to extend into the leadmine district. Its width is 17 feet, and it supplies materials for nearly all the turnpikes within 10 miles on each side, both in the north east corner of Yorkshire, and the southern edge of Durham.

The *Great Whinsill* is a stratified or horizontal mass conformably arranged near the middle of the carboniferous or mountain limestone, and may be traced even from Cross Fell to the bed of the river Tees. In some places the thickness is about 6 fathoms, in others 20 or 30. It consists of basalt, coarse grained in texture, and composed of white feldspar, and black hornblende: the latter mineral predominating and giving the rock a dark greenish grey colour. It is supposed to form the

cascades of Caldron Snout, High Force, and to extend as far down the Tees as Egglestone Abbey a mile below Barnard Castle, where it forms some of the beautiful scenery of "Rokeby." Sir W. Scott calls it, here, "Porphyry."

The basaltic beds of Derbyshire often alternate with the carboniferous limestone, and generally in three beds. It is here called *Toadstone* from its spotted appearance resembling a toad's back. The basalt of Staffordshire forms a number of hills around Dudley. The streets of Birmingham are paved with it, where it goes by the name of Rowley-rag: the village of Rowley standing on the highest of its hills. The Titterstone Clee -hills of Shropshire are of the Rowley-rag, and are connected with a dyke of 100 feet in width.

It would greatly exceed our limits to enumerate all the basaltic beds and whin dykes that alternate with the Pennine rocks or traverse the coal measures. Some of the mountains near Ulswater are capped with basalt, and basaltic ranges are common in all parts of the world, forming both the highest and lowest rocks; and, in some measure, serving as geological chronometers and indices that point out the subsidences, which have new modeled a considerable part of the earth's surface since the formation of the transition rocks down to the latest series. The trap of Northumberland at and near Holy-Isle, the Great Whinsill and the toadstone of Derbyshire seem coeval with the Pennine Chain, and, of course, prior in formation to some of the metallic veins. Yet the Cleveland dyke is in the oolites, and in the Western Isles the basalt of the Giant's Causeway overlies the lias, and in Ireland even the chalk. The Giant's Causeway we therefore suppose was formed at the subsidence of the Atlantic continent, at which time perhaps the British primitive mountains were depressed to their low elevation when compared with the Alps.

That the Giant's Causeway was originally deposited under the ocean, or at least that the ocean swept over it before it was solidified, is evident, since it appears to have had a horizontal surface uniform with the summits of its highest cliffs, and all the inequalities of its surface are obviously occasioned by the materials, which filled the valleys, having been washed away. Now had the whole mass been solidified previously to the retiring of the ocean, no force of water would have so scooped out the valleys, and left the promontories standing And as the effused basalt rests upon the chalk, may we not

suppose that the unindurated materials, uniting chemically with the water, were floated to a distance by the ocean, and that a portion of them was deposited in the great European basin and formed the Plastic Clay. The subsidence of the Irish Sea perhaps took place at the same time; though this seems to have been principally occasioned by a subsequent subsidence of the whole British continent, or of Great Britain and Ireland, when the primary rocks sunk to the sea-level, and, of course, the water overflowed the later formations.

That all the trap or basaltic formations have been ejected from the bowels of the earth in a fluid state, though occasionally blended with the contiguous materials, is very evident from the number of dykes mostly found connected with them. In the western promontory of Bengore, Giant's Causeway, no less than 11 dykes have been observed, with a slip of 30 or 40 feet. Throughout the whole range of the Western Isles, there is scarcely a rock which is not intersected by basaltic veins or dykes of various forms, according to the nature of the rocks which have been split for their reception.

That the liquefaction was caused by heat is no less evident, since the rocks which they cut through are always, in the contiguous parts, changed as by the action of fire, and *that* sometimes to a considerable distance. In some instances the trap graduates into the containing rock, a proof that the latter had contributed to the former; but in other cases, the fused rock constitutes a new substance by itself. Thus: grit becomes compact quartz; shale becomes flinty-slate, or porcelain jasper, or even both as in the Western Isles and Ireland; where shale contains organic remains, it is by the contact of trap converted into Lydian-stone. Limestone becomes highly crystallized, and coal is invariably charred. A variety of the inferior kinds of precious stones are also frequently found in contact with the trap; in one or two instances, strings of lead are found between it and the divided rock; but such strings no where penetrate the basalt, though in the beds of Derbyshire toadstone, the ore seems, in some instances, to be mixed with it.

9. VOLCANIC PRODUCTS.

These are the substances ejected from volcanoes. In some countries they form a very important class, and in all are much more numerous than is generally supposed. They consist of

pumice-stone, obsidian or volcanic glass, tufa, and volcanic breccias, which, when ejected in a fluid state, are mostly included under the general term *lava*. Sulphur is usually among the products of regular volcanoes, and almost all extinct volcanoes become sulphur mines. In some old craters are also found gold, mercury, and several other materials.

The explosions of volcanoes are always preceded by earthquakes, and tremendous noises,—at length the lava flows over the top of the crater, or breaks out from the sides of the mountain, sometimes covering hundreds of square miles of the neighbouring plain with melted matter of several yards in thickness. Intensely black clouds of pulverized pumice often form over the crater, which towards the conclusion become white. By one eruption of Ætna an area of 50 miles diameter was thus covered 12 feet thick. Some volcanoes emit torrents of water mixed with mud, and stones—liquid chalk has also been ejected, and at the commencement, masses of rock of most enormous size are projected to an immense distance.

Lavas are chiefly composed of feldspar and hornblende, the same as the trap rocks, of which they are a mere continuation. They often contain large imbedded crystals of garnet, leucite, olivine, augite, vesuvian, and zeolite; and they frequently resemble scoria from a furnace. When lava is light coloured, porous and fibrous, it is called *pumice-stone*. The island of Lipari contains a mountain of white pumice, whence England is chiefly supplied:—it is principally feldspar. Pumice has been met with floating on the sea, covering a tract of 300 miles in extent, at a great distance from any known volcano.

Obsidian or volcanic glass nearly resembles common black glass; but it is harder and strikes fire with steel:—though it is sometimes porous and spongy. In Lipari is a mountain of it,—veins of it intersect the summits of Vesuvius, and it it is found in most volcanic districts. It sometimes, as on the Peak of Teneriffe, graduates into pitchstone. Obsidian is melted basalt cooled very suddenly.

Pulverized pumice, when ejected and deposited on the earth's surface as above described, by the action of rain and the air, indurates into *tufa* used for building stone. A variety containing a greater quantity of alumina, when mixed with two-thirds lime, forms a cement that sets under water, known by the name of *tarras* and *puzzolano,* which are sometimes made artificially by burning clay-slate that contains iron.

Submarine volcanoes are attended by a violent boiling and agitation of the water, with the discharge of gas which inflames when it comes in contact with the air, and spreads in sheets along the waves. Masses of rock are sometimes ejected that soon raise the crater above the surface of the sea, but at other times, the rock rises *en masse* above the waves and remains a black reef. In 1783 a submarine volcano broke out near Iceland, raged for several months, then subsided, leaving only a reef of rocks. An island was formed among the Azores in 1720, nine miles in circumference;—it afterwards sunk to the level of the sea. In 1811 a large black rock rose near St. Michael's, one of the Azores. It was visited by the crew of an English frigate, the Sabrina. The captain left his flag staff on it—came to England with the news—was sent back with a commission to take formal possession of it;—but when he arrived at the scene, both island and flag staff were gone! There are now 80 fathoms water in the place.

Submarine volcanoes have been frequent in the Archipelago. An island was formed near Santorini in the year 1767, and many such formations are stated to have taken place in the last two thousand years. Three of the more ancient are recorded by Pliny, Strabo, and Seneca. Indeed not only the Archipelago, but the whole tract from Ætna to Mount Arrarat, seem to be placed on an active volcanic mine.

It would far exceed our limits to enumerate all the volcanic districts, few primary or even transition mountains are without them either active, dormant, or extinct. The sea is in many parts of the world besprinkled with volcanic islands, even most parts of the West Indies exhibit traces of them; the Caribees, Martinique, Guadaloupe, and St. Lucia, might be especially instanced, Montserrat contains one in an active state. A great many lakes seem to owe their origin to the subsidence of volcanic craters. It has been remarked that the shocks of earthquakes always seem to those in the neighbourhood of lakes to proceed from them; and the frequently violent agitation of the waters in the Keswick and some other Cumbrian lakes, indicates something of a volcanic action. In some instances large tracts with cities upon them, as was the case with the city of Euphemia in 1638, have sunk down with their inhabitants and for ever disappeared, leaving only a lake behind; and of the same nature was perhaps the fate of Sodom and Gomorrha, and the origin of the lake Asphaltes or Dead Sea.

But we have at least one instance of a mountain or hill rising out of a lake; viz. *Monte Nuovo*, which in the year 1538, rose, in the space occupied by the Lucrine Lake, to an elevation of 600 feet, and a circumference at the base of 4 miles. In 1750, a volcano broke out in an elevated plain, that was in a state of cultivation, within six days journey of Mexico. A tract of ground of 3 or 4 square miles in extent rose up like a bladder to an elevation of 524 feet. Flames issued out of the ground, fragments of red hot rocks were thrown to a prodigious height, through a cloud of ashes illuminated by the volcanic fire;—two rivers precipitated themselves into the burning crevices, and their waters increased the flames. Thousands of small cones were formed, which still contain considerable heat, and emit smoke that rises to the height of 12 or 16 yards. In several, a subterraneous noise is heard, like a fluid boiling at no great depth. Six new mountains of a much higher elevation were formed, which still remain; the largest of them is now called, the volcano of *Jorullo*. The whole of the mountainous part of Quito, occupying more than seven hundred square leagues, and throwing out flames from different cones, as Cotopaxi, Tinguraghura, and Pichincha, is supposed by Humboldt to be one volcano; and there are not less than 42 volcanoes, some active, among the Azores.

In old volcanoes, such as Ætna, the Peak of Teneriffe, and some of those among the Andes, the eruptions are after intervals of almost a century; while Stromboli and others of small elevation are continually active.

Closely allied to volcanoes are hot springs, which generally prevail in volcanic and basaltic districts. A few minutes before the shock of the earthquake at Lisbon, 1755, the hot springs at Toplitz in Bohemia ceased for a minute, and then burst forth with prodigious violence and a higher temperature, which has continued ever since. The hot waters at Bristol became of a red colour, and continued so for some months

The corroborating evidence of our theory, arising from volcanoes, is very great; but it must not be omitted, that by some speculative geologists, they will be thought to prove too much, and therefore nothing. For there are theorists who ascribe the origin of all the primary and transition mountains to an internal volcanic power, acting beneath and protruding these rocks through the later formations. This power they ascribe to the expansive force of gas or steam, without saying, as far as we

can discover, when they have got a range of mountains elevated how it is suspended. A weight suspended by a body of aeriform substances, unless these substances be in an air tight and unchangeable reservoir, and at an equable temperature, such as the mountains perforated by volcanoes or emitting springs sometimes of hot water cannot be, would be in a constant tremour. However, we perhaps do not essentially differ from these theorists; for we suppose that the primary and transition mountains were partly protrusions of internal parts of the earth's surface, and, to a certain degree, of elevations of the external shell. But, we affirm that the protruding force was not gas or steam; but the subsidence of a large area of the earth's surface, and the unequal pressure thereby caused on the fluid nucleus of the earth. As when a puddle-hole of two or three feet diameter, with an inch or two of water, is cased over with half an inch or so of ice, and we tread on the centre, the puddle rises up round the edges, while the centre subsides. Transfer this principle to the great European basin, or the Pacific Ocean on the western side of South America, and we have the Alps and the Andes as parts of the surrounding edges of our subsidences.

That we may have the weight of the foot; suppose the earth, at a certain period, like an orange, with the sea surrounding the whole at an equable depth, the earth's centre of gravity would therefore be the exact centre of the mass. Now, at this period the developement of the electric fluids would be inconceivably greater than at present, and discharges or shocks similar to our earthquakes would be frequent: suppose a shock took place at the time of high water in a spring tide, this might cause an indentation of the earth's shell, into whose cavity the ocean would be immediately drained. The equilibrium of the earth's surface would be consequently destroyed: the contained water being the weight of the foot on our puddle hole, and as the process was continued, lesser indentations would be swallowed up by greater subsidences.

We might mention several recent subsidences of the earth on a small scale; and, perhaps, it would not be too much to ascribe the action of volcanoes to subsidences on a large scale. It is certain that volcanoes are generally in lines or strings,—the new ones, of which Jorullo is the chief, are ranged along a fissure that has been traced to an immense distance; the new mouths of Vesuvius are along a rent that intersects the moun-

tain; and, generally, when one volcano of a chain is very furious, all the others shew less or more activity. Indeed it would be difficult to conceive how a volcano, Ætna for instance, could emit such a pile of matter from beneath its foundations, without subsiding and being ingulfed in its own ruins. Is it not more probable, that by a subsidence of the earth, caused by the weight of the Mediterranean, fluid matter is pressed from a distance towards the foundation of the volcano, and finally finds vent at the orifice, which, coming into the comparative vacuum of the atmosphere, is, by the expansive force of heat, dispersed with the various phenomena that attend an eruption?

COAL FORMATIONS.

THE concluding remarks of the last section will properly introduce the subject of the present. For as we have supposed the inequalities of the earth's surface to have been occasioned by subsidences, and consequent change of place of the ocean; and as the waters were stocked with living creatures (shell-fish), and the land supplied with vegetables,—*these* must have been ingulfed along with the earthy materials, and we must expect that traces of them will still remain. Now although there might be few organized bodies at the first subsidences; yet, perhaps the sea was as pregnant with life, and the dry land as abundant with vegetation before the formation of our primary rocks, as they have ever been since. There are two reasons, besides that stated at Sec. 4, why organic remains should not be found in primary rocks: the one, because they would be blended with such a vast quantity of earthy materials as must necessarily make them appear comparatively few:—the other, because these earthy materials would be solved by heat, consequently the organization would be destroyed: the shells would be converted into primitive limestone, and the vegetables into anthracite, or assist in the formation of bituminous slate.

We shall therefore consider the primary rocks as destitute of organic remains; in the transition are found, though but sparingly, corals, encrinites and testacea; the mountain limestone seems almost composed of these and certain others with occasional vertebræ of fish, shark's-teeth, and many singular palatal tritores and the radius of a Balistes. The same may be traced through the millstone grit, with the addition of nodules of ironstone containing muscle shells. The coal measures present few

shells, and it is doubtful whether those they do contain are fresh water or marine,—by some it is believed they belong to both. The organic remains in the magnesian limestone, which rests on the coal measures, are very rare; and the new-red-sandstone contains none, which seems, as it were, to mark the interval between an old and new world,—for all the organic remains in the succeeding formations are different, with very few exceptions, from those contained in the rocks we have been describing.

We find the same similarity prevail among the *vegetable* remains throughout these formations, that is observed among the animal. The first occur among the upper strata of the clayslate, the lowest of the transition series; these, with the few that are met with in the intervening formations partly agree with the vegetable remains of the coal measures, which besides abound in ferns, flags, reeds of unknown species, and large trunks of succulent plants, strangers to the present globe, and more nearly agreeing with the productions of the torrid zone than with those of the temperate, and with moist rather than dry situations. "All the strata incumbent on coal contain a great variety of vegetables or the impressions of them; and particularly the bamboo of India, striated and jointed at different distances; the Euphorbia of the East Indies, the American ferns, corn, grass, and many other species of the vegetable kingdom, not known to exist in any other part of the world in a living state. They are inclosed in the solid substance of stone and clay. The Schistus beds in the Holling Hill pit near Felling, affords beautiful specimens of fine cones, ears of barley and roots of turnips, the last of which are converted into iron-stone. In the schistus beds in the colliery of South Shields are also frequently discovered the shells of cockles, and other marine animals. Sometimes large trees are found extending out of the strata of indurated clay, into those of sandstone as at Kenton, where are seats of stone hewn out of these remarkable fossils, that shew the yearly rings of the tree, and the roughness of the bark. As far as the rock was cut through, this tree could be traced even to its smallest branches, and the stratum in which its roots were fixed seemed one uninterrupted continuation of vegetable impressions." See "*The Picture of Newcastle-upon-Tyne.*"

In the great revolutions or subsidences to which the surface of the earth has been subject, vast quantities of trees and other

vegetable productions, as well as some animal substances, have been swept into the indentations or cavities, (or by such alluvial processes as are now going on in the river Mississippi, have been deposited in lakes, friths, and estuaries of the sea,) and covered up with earthy materials: these by various processes of decomposition have been converted into the several varieties of coal, which we are about to enumerate. All coal, therefore, has had the same vegetable origin, but the decomposition has been different in every rock or formation, being the most complete or carried on to the greatest extent in the oldest rocks; and, therefore, each formation from the primary mica-slate—to the alluvial of the present day, has its peculiar kind of coal.

1. The most ancient kinds of coal are the beds of *anthracite* and *plumbago* contained in the mica-slate, and some other rocks classed among the primaries. The process, which has converted vegetable substances into these, is, in principle, exactly the same as that carried on in our gas works;—so that these beds may be considered as the *coke*. Where the coal was exposed to the air, the whole of the carbonaceous matter was dispersed, and we have only beds of martial pyrites remaining:—sulphur and iron being abundant in all the older coal formations.

2. As the transition and all the trap rocks were principally formed in the medium of heat,—the latter being completely fused and the former partially so,—in both cases the bituminous parts of the coaly or vegetable materials would be dispersed:—hence the same beds are found amongst the transition and trap formations: but as the fusion of the transition was only partial, so we often find bitumen in the crevices of these rocks, and also in the rocks of the Pennine chain, though a coal approaching in character nearly to that of the great coal formation occurs in the latter, with abundance of bituminous springs.

3. Hitherto the vegetable deposits have been subject to heat, so as in some cases, as among the primaries and trap formations, to disperse both the carbon and hydrogen,—in others the carburetted hydrogen gas;—and in others merely to cause a liquefaction, (for coal is very fusible when submitted to heat in close vessels so that its parts cannot evaporate,) when its bitumen, which is carbon and a large quantity of hydrogen forming coal oil, was separated, as among some of the transition and the Pennine rocks: but we now come to those deposits which have suffered comparatively little from heat.

A great many experiments have been tried on wood and the different kinds of coal with various results: though all tending to prove the vegetable origin of coal, yet not satisfactorily proving the gradation from wood, through lignite, jet, common coal, bitumen, and anthracite to plumbago the other extreme of the carbonaceous series. However, it should be remembered, that no process in the labratory can be exactly assimilated to that which must have converted vegetable matter into coal.—First, we have a space of time of four or five thousand years; we have the presence of water in some cases, and perhaps its absence in others; then we have heat—nevertheless no formation posterior to the new-red-sandstone, has been affected by heat;—consequently the coal of the next succeeding series, the lias, is only jet. But Dr. Macculloch's experiments seem to prove, that jet, submitted to heat under pressure, becomes coal. The coal beds are buried beneath strata of shale and sandstone of many hundreds of feet in thickness, we therefore have a sufficient pressure. The new-red-sandstone which overlies the coal measures, and therefore of posterior formation, in some places graduates into trap, shewing that the temperature of the earth's surface must have been very great since the deposition of the coal measures. We suppose the coal strata, then, to have been affected by heat;—but a different heat from that which changed the new-red-sandstone into trap, or remodelled the transition and primaries:—the heat of the coal being only that of steam or distillation, though perhaps urged to a higher temperature than can be effected in the labratory, while the heat of the trap, transition and primary was similar to that in the process of smelting ores.—And, lastly, while the earth's surface was at this high temperature, electricity would abound to a proportionate degree, with frequent discharges, or earthquakes. We have, therefore, not only time, water, heat, pressure, but very high charges, and occasional shocks of electricity, to assist the decomposition, or if we may be allowed the expression, the *digestion* of vegetable substances into coal.

The above remarks principally apply to what is called "the great or independent coal formation, which is that included between the old and the new-red-sandstone. The quantity of vegetable matter which must have contributed to the formation of this coal, must have been inconceivably great, and seems to indicate a complete change in the earth's surface. For this

reason we have considered it as marking the curse pronounced upon the earth. (see Introduction). This formation is the proper subject of the present section; but that we may have the advantage of contrast, and may not hereafter have to turn aside, we shall here enumerate the other coal deposits, which are very trifling and insignificant when compared with the present.

4. The new-red-sandstone, is said, on the continent to contain occasionally thin seams of coal, though no mention is made of any such in England. In the table land of Santa Fé, Peru, 1360 toises above the sea level, as also near Huanuco, at an elevation of 2,300 toises, near the limits of perpetual snow,—beds of coal are interposed in this formation.

5. The oolite series, contains different kinds of coal. In the sands immediately on the Lias, is jet, as at Whitby; and in other places there are said to be regular strata of workable coal, though of inferior quality, accompanied by vegetable impressions. And the Kimmeridge clay contains beds of *bituminous shale* affording an imperfect fuel.

6. The sands between the oolite series and the chalk contain thin seams of a kind of *cannel coal,*

7. A variety of *lignite* occurs with the plastic clay formation, in the Isle of Wight, in the Paris basin, in the north of France and other parts of the continent, alternating with beds of sand and silt, and fresh water shells.

8. Associated with the basalt in the north east of Ireland, and in almost every tract of the same formation on the continent, especially in Hesse and Bohemia, is a *lignite,* which seems to have originated with the subsidence that gave birth to these formations, when vast forests were entombed by the concussion.

9. But the most extensive deposit of *lignite* is that of Bovey Heathfield, near Exeter. It consists of several beds of somewhat different kinds of coal, separated by strata of clay, and sand and gravel. At about 73 feet below the earth's surface are immense layers of timber, disposed horizontally over each other. The uppermost trunks still exhibit bark little altered, and the woody fibre completely ligneous, Beneath, the wood is more comprest; but still, in places, the laminæ of the coal undulate, having the appearance of the roots of trees. In the neighbourhood of the coal field are found trunks of fir trees, with their roots fixed in the ground; hence it is inferred that the coal was formed from wood of this kind. The lowest bed is

17 feet thick and rests upon clay, under which is sand resembling sea sand. The coal is mixed with earth and is of the kind, called brown coal.

On the banks of the Rhine between Cologne and Bonn is a deposit of the same kind. The bed of coal is 50 feet in thickness, and extends over many leagues. It is covered with a bed of gravel from 12 to 20 feet thick. In this coal are imbedded trunks of trees with their branches stripped off, which proves that they had floated from a considerable distance, and had been in their passage much tossed in the contending waves. Nuts, which are indigenous to China and Hindostan, and a resinous substance such as is produced only in warm climates, are also found among them.

These formations doubtless originated in the same manner as these depositions now going on in the Mississippi; --but as that of Bovey Heathfield is deposited upon secondary rocks,—it must have been formed posterior to them. Bovey Heathfield is an extensive tract of flat marshy ground, surrounded nearly by secondary hills, which undulate at the foot of the primaries of Dartmoor. In the present state of this part of the island, there is no trace of a river sufficient to produce such an extensive deposition. The country all around has extensive formations of overlying trap; and we have already stated our supposition that the Bristol Channel, as well as the British Channel, were formed by subsidences posterior to the oolitic series;—might not, therefore, these trap formations originate with such subsidences;—and might not the source and channel of this great river be upon the subsided Atlantic continent.

10. *Alluvial, Peat,* and *Moss.* This is the latest formation, and in some places is every day receiving fresh accumulations. It sometimes consists of submerged forests covered with sand and alluvial vegetable productions, but its chief accumulation is by the growth, *in situ*, of the sphagnum palustre, and by the waters draining from the neighbouring eminences and depositing their vegetable matter. This matter is chiefly composed of tannin that combines with the water:—hence human bodies have been preserved in mosses for many centuries, by means of the gelatinous substance of the skin &c. being converted into leather. Peat moss often graduates into a kind of jet, or hard stony-coal,--presenting a kind of unmatured coal formation. The lower beds of Bovey Heathfield are of this kind, and it has

been supposed that the alluvial matter was deposited on a peat moss. They often contain marks of human ingenuity.

The Coal Field of Northumberland and Durham, or *The Newcastle Coal Field* extends over a large area of the eastern parts of these two counties; and is from north to south about 58 miles; and, at its greatest breadth from east to west, about 24:—the whole surface of the workable coal is calculated at 180 square miles.

The series of the Pennine rocks dip beneath the coal measures, and these again at the east, dip beneath the magnesian limestone, a subordinate of the new-red-sandstone. The coal strata, dipping from the circumference towards the centre, give the idea of a basin. And as the seams are at the greatest depth at Jarrow—this has been assumed as the central point. Jarrow is on the southern banks of the Tyne, five miles from its mouth, and the *high main* seam is 320 yards below the grass. The strata, therefore, on all sides rise toward the surface, and that with an average of one inch in twenty, though this is irregular: consequently, they all basset out to the westward before the millstone grit is seen at the surface. In some places the outcrops are visible; but they are oftener hid beneath diluvial or alluvial materials; among which are fragments of hard black basalt, and other trap rocks from the Cheviot, and masses of fine grained granite. As the central point is so near the German Ocean, the sea must cut off a great deal of this coal field and wash a way its strata:—hence, after a strong north-east wind, the coast, especially near Hartlepool and the mouth of the Tees, is covered with small coal, which is carefully collected for fuel.

No less than 40 beds of coal have been enumerated in this field, though some of them are very insignificant: the two most important are the *High* and *Low Main*. The thickness of the first is about 6 feet; and that of the second 6½ feet. They are 360 feet asunder; and the upper one is, at Newcastle, about 135 fathoms from the surface. Between them are 8 thinner beds; and 7 have been observed beneath the low main; but the coal of the latter is of inferior quality, graduating into that of the millstone grit and shale. The coal beds and intervening strata differ much in different places as to thickness—the whole series being about 1620 feet; the whole of the coal beds 44 feet, in which are eleven beds not workable, and five more scarcely so, hence

there are only 36 or 30 feet of workable coal, and an area of 180 square miles--which gives 5,575,680 cubic yards. According to the present rate of consumption, and after making ample deduction for the quantity already consumed, waste &c.,—it is concluded that it will be 800 or 1000 years before this field is exhausted.

The coal measures often form hills exceeding 1000 feet in height; but the inequality of the surface does not affect the dip or inclination of the strata; so that when they are cut through by a valley, they are found at the same level in the side of the opposite hill, proving that the scooping of the valleys was of posterior date. However we must here make an exception in favour of the depression of the strata by slips. For all the coal fields, besides the dykes of the trap formation, are intersected by dykes or fissures of unknown depth. These dykes are generally filled with clay and fragments of rocks from above; but they sometimes contain hard and soft sandstone. The most remarkable of these is called the *main*, *great*, or 90 *fathom* dyke. In some places the width is not great, but in others is 22 yards. It runs from the coast about 3½ miles north of Tynemouth, where it contains a small string of galena; passes at about 2½ miles north of Newcastle; and crosses the Tyne near Lemington. The slip or down cast of the strata at the northern side is 90 fathoms. Two others branch off from the southern side, one of which is 70 yards wide, and has charred the contiguous coal, the only instance of this kind except in whin dykes. The coal strata are often very much broken, and thrown into great confusion by these dykes, slips, faults, traps, steps, hitches, or troubles, (for they are known among the workmen by all these names). Yet they have their use, and in fact the coal field would hardly be workable without them :—for, as they are filled with clay, they form an impenetrable barrier to water, and thus divide the field into basins, each of which may be drained without being incommoded by the water of a neighbouring basin, for which reason the miner is very careful not to perforate them.

There are about 25 beds of *sandstone* in the coal measures. Most of them are thin; but one crops out on Gateshead Fell 60 feet in thickness, from which Great Britain, and even some parts of the continent, are supplied with grindstones. The sandstone, is usually gritty, micaceous, or tender—the last is used for filtering stone; but it often affords tolerably good

freestone; some varieties of a large schistose structure are used as paving flags, others more finely laminated make roofing slates. It is locally termed *plate, post, pennant,* and when very hard, *whin.*

The *slate-clay* differs from the transition clay-slate, being less solid, or in texture shewing no approximation to crystallization. It is known by the names of black, blue, or grey metal, shale or shiver, clunch, cleft, bind; and when very hard, *whin.* The beds are, in number, about 32, they are generally thinner than the alternating sandstone, and indifferently with the sandstone form the roof or floor of the coal; though a hard bituminous shale used in making *fire* bricks often forms the floor.

The accompanying minerals of the coal strata, are clay-iron-stone, forming thin beds or nodules in the strata of the shale, which nodules often contain galena and martial pyrites; calcareous spar and blende,—the former is common, the latter only occasionally occurs. The iron-stone is both in strata and beds of nodules, provincially termed Mine and Pins;—it is very abundant in the coal fields, and usually affords an average of 30 per cent. of iron. As we suppose the earth's surface, in consequence of the *curse,* to have been re-compounded since the creation, the occurrence of iron, the material for all instruments of manual occupation, in immediate contact with fuel for manufacturing it, is too remarkable not to be attributed to design:—may we not say, that the Creator, when he condemned man to labour, provided him with materials and work; and that, even in the day of wrath, he was mindful of his mercy?

In the long interval between the southern extremity of the Durham coal-field, and the northern extremity of that of South Yorkshire, where the magnesian limestone comes in contact with the millstone grit, shale and carboniferous limestone, are several thin strata of coal; but they seem referable to the millstone grit, and leave no room for the conjecture that the coal field might be overlaid by the magnesian limestone, and that these are its outcrops, although

The *Great Coal Field of South Yorkshire, Nottingham and Derbyshire* seems to emerge from beneath the magnesian limestone, under such circumstances as might warrant us to conclude, that it is a continuation of one and the same field, only overlaid, not cut off, by the magnesian limestone. Whether it is so seems to be a geological problem, a solution of which is a great desideratum both in a scientific and statistic point of

view. The greatest length of this coal field from Leeds to Nottingham is about 60 miles, and its greatest breadth about 22 miles; there are 30 beds varying in thickness from 6 inches to 11 feet, supposed to form a total thickness of 26 yards; so that the importance of this field is thought to surpass that of the Newcastle coal-field.

There are 20 beds of *sandstone,* which is somewhat more gritty than that of Northumberland; and some of the shale called *clunch,* is more of an indurated clay. A bed of ironstone 8 or 10 inches thick abounds in muscle shells, and is worked as an ornamental marble. This coal-field is traversed by dykes; and it suddenly terminates near Nottingham, being cut off by the horizontal beds of the new-red-sandstone.

Were we to consider the coal measures as much posterior in formation to the Pennine rocks, and deposited in the manner of some of our peat mosses, with the assistance of alluvial deposits like those of the Mississippi, we might suppose them to have formed vast lakes or estuaries round the Pennine chain. Both the fertility of most parts of these rocks, and the position of the coal measures favour such an hypothesis (but let it be added that this position is equally favourable to our theory):—consequently pursuing the Pennine chain to westward, we find several detached coal-fields.

At the south-west point are those of *Cheadle* and *Newcastle-under-Line.* The *former* is an insulated basin of the lower strata of the great coal-fields.—the southern portion being pro bably overlaid by the new-red-sandstone. The *latter* is called the pottery coal-field, and consists of about 32 beds of from 3 to 10 feet thick. The *Manchester coal-field* is of considerable importance, and contains about 50 seams; some parts of it are very much disturbed by faults; and the new-red-sandstone has apparently insinuated itself into the fissures; but there is, as yet, no scientific account of this coal-field. Pursuing the Pennine chain northward, we arrive at an insulated basin between Lancaster and Ingleton, remarkable for being separated from the transition slate by only the mountain limestone of Ingleborough. A part of the Pennine chain nearly surrounds the primary and transition mountains of the Cumbrian lake district; at the north-west corner of which is the *Whitehaven coal-field.* This field ranges along the coast, chiefly to the north of Whitehaven, about 40 miles, forming a surface of about 100 square miles. In the depth of about 165 fathoms they work 7

large beds, from 4 to 10 feet thick, and notice 18 thin ones. The strata dip rapidly beneath the sea about *one* in *ten*; and in one place they have been worked 1000 yards under the sea. The faults run from east to west, with 120 feet slip. Near the foot of Cross Fell, as may be seen by the cut, are thin, almost vertical *beds of coal;* but they are greatly shattered and deranged by the great subsidence which has there its limits.

Besides the great Pennine chain, its rocks protrude in several places through the new-red-sandstone; and also skirt a great many parts of the transition mountains; and they are almost invariably accompanied by *coal fields.* Between Ashborne and Derby are indications of coal, and further south, on the northern skirts of the transition formations of Charnwood Forest, is *Ashby-de-la-Zouch coal field.* It extends about 10 miles by 8. The beds are much disturbed by faults, and one of them is from 17 to 21 feet thick.

The *Warwickshire Coal Field* is about 16 miles by 3; the deepest pit 117 yards, and at a junction of two beds, is a seam of 15 feet. *That* of Dudley or South Staffordshire is about 20 miles in length and 4 in width:—having an area of 60 square miles. It affords many seams of 4, 6, or 8 feet in thickness; at the southern point is the thickest coal seam hitherto found—being 30 feet. There are 11 beds. The lowest is at about 313 yards, and seems to rest on the transition limestone.

The *Somersetshire and South Gloucestershire* coal-field is about 25 miles in length and 11 in breadth,—and is cut into two nearly equal parts by the river Avon. It is supposed to contain between 50 and 60 seams,—but the thickest of them hardly exceed a yard. The strata are much deranged, being sometimes vertical or even thrown backward, with slips of more than 100 feet. It is overlaid by the magnesian limestone, new-red-sandstone, and the lias.

The above coal-field may be considered as a detached corner of those which surround the Welch transition mountains, and as separated by the subsidence which gave birth to the Bristol Channel. By far the most important of them is that of *South Wales.* It contains 12 beds of from 3 to 9 feet thick, making together 70½ feet; and 11 others from 18 inches to 3 feet, making 24½ feet; and other thinner beds; with an area of 100 square miles;—so that this field perhaps contains more workable coal than either that of Newcastle or South Yorkshire. Its lowest beds are, in some places, near 700 fathoms below the

distant outcrops of some of the upper seams; but as the field is intersected by deep valleys, the miner, in many cases, only drives a level from the hill side, into the beds of coal and clay-ironstone. It is traversed from north to south by immense faults; and slips of from 50 to 100 fathoms.

The *Coal Field of North Wales or Flintshire* extends from Llanassa to near Oswestry, Shropshire, more than 30 miles. It contains beds of near five yards in thickness, which dip one yard in four. In the isle of Anglesea is also a coal basin.

In the vale of Shrewsbury are many broken patches of coal strata, where the new-red-sandstone comes in contact with the transition. In the south east is the Wrekin (serpentine and trap) chain, and on the eastern side is *Coal Brook-dale coalfield;* and a few miles south, those of *Clee Hills and Billingsley*, *Titterstone*, *Abberley Hills*, and some other patches. They are chiefly insulated basins, and their strata dip on all sides towards the centre. Trap greatly abounds in their neighbourhood. The last of the coal-fields which we shall mention, as skirting the Welch mountains, is *that* of *the Forest of Dean*. Its length is about 10 miles and its breadth 6. It contains about 17 beds with a total thickness of 37 feet;—the strata all dip towards the centre.

The principal *coal district* of Scotland is included between the transition Cheviot on the south, and the primary Highlands on the north;—the whole of this space is occupied by the old-red-sandstone, the Pennine rocks, coal measures, and perhaps, though it is not yet decided, the new-red-sandstone. Geologists endeavour to trace these coal measures, together with their bounding primary and transition, into Ireland;—which island, with the exception of the basaltic district of the north-east, seems entirely composed of these formations, and nearly in the same order:—the central area consisting chiefly of separate coal formations. They also attempt to trace the same series from Scotland eastward, through Sweden towards Russia;—in which tract are occasional coal-fields. On the boundaries of France and the Netherlands are very extensive coal-fields, reaching from Boulogne to Valenciennes, thence along the Scheldt and beyond Aix-la-Chapelle and perhaps to the coal district of Germany. A coal-field in the forest of Ardennes is bounded by transition slate and graywacke,—accompanied by the Pennine rocks. Some of the French coal measures extend beneath the chalk:—the English intervening beds being occa-

sionally wanting. In the south of France are some small coal-fields: coal has also been found in Spain, namely, in Catalonia, Aragon, and New Castile. In Germany are many coal-fields some overlaid by both porphyry and syenite. Coal occurs plentifully in Bohemia and Upper Silesia. It is also found tothe north of Constantinople, and in several parts of Russia and Asia; extensive mines are worked in China; it abounds in the northern parts of Japan, in Van Dieman's Land, in the plains of the Mississippi, and at Philadelphia and in other places of North America, as in those parts which Captain Franklin visited, where is a mountain on fire. In the northern parts of Siberia is a coal formation that has been burning for centuries.

We have perhaps devoted more than a due share of our pages to the coal-measures;—but when we consider that our preeminence in manufactures, and consequently the chief of our trade, rest principally on our favourable position with respect to iron-ore, coal for fuel, and lime for flux, we may not improperly say, that we have thus dilated, not only upon a great sourse of domestic comfort, but also upon the *chief source* of our national wealth and grandeur.

11. NEW-RED-SANDSTONE.

Or *Red Marle, Red Ground, Red Rock* or *Saliferous Sandstone,* and its subordinate, *Magnesian, Newer Magnesian, Conglomerate or first Floetz Limestone.*

THIS series appears to be composed of the debris, detritus, and chemical solutions of all the former rocks, floated or impelled to a distance by the waters of the ocean, and deposited in horizontal strata around their bases; so that, in many places, they seem like small islands projecting out of this sea-like formation. It therefore, differs much, both as to composition and texture, in different places; and comprehends a vast variety of ingredients.

The Magnesian Limestone. The lower beds, called the magnesian limestone, are chiefly lime, sometimes containing breccias or conglomerates of the mountain limestone; but its general mass differs widely from that formation, especially by its containing a large portion of magnesia. However, both the transition and mountain limestone, occasionally contain subordinate

beds of magnesian limestone;—such beds likewise occur among the primaries, and are called *dolomite*.

This formation, in its range from Sunderland to Nottingham, differs much in different places. Some of its beds contain no less than 45 per cent. of carbonate of magnesia, while others contain only about 20. Towards its bottom are occasionally found thin beds of almost pure carbonate of lime, imbeded in blue clay and abounding in anomia and other shells. In many places are partings of clay mixed with oxide of iron, and sometimes manganese. It occasionally contains sulphuretted hydrogen, in botryoidal masses devoid of magnesia. These are often in balls varying in size from a pea to two feet diameter, radiated from the centre, of a brownish colour, and glassy like fracture. They sometimes contain calcareous spar; which often abounds in the fissures of this formation. Its conglomerate beds are occasionally disposed throughout the whole formation, but they generally separate it from the overlying sandstone.

Its prevailing colour is buff, but it has various shades of yellow, as also fawn and salmon colour; sometimes, especially near the partings, it is of a brown or reddish hue, where it is often dendritic; and where sand enters into its composition it is occasionally perfectly white. Its texture is generally granular with a sandy looking structure, and a glimmering lustre. In several places it exhibits signs of an igneous formation, or rather perhaps of electro-chemical disturbance, as if the shock had partly fused it;—consequently, it presents such an appearance as we might suppose would result from passing an electric shock through a number of thin cakes of wax. It is therefore strangely arched and contorted, with fissures, cavities, and a semi-crystalline texture, when it is so hard as to resist the stroke of the hammer: nevertheless, in the same quarries are beds of regular stratification with every variety of inclination, and also masses of rotten stone. However, most of its horizontal beds have an earthy appearance, and such a texture as we might suppose would result from a deposition from water with mere induration. This is generally the buff coloured, and it affords a good building stone that hardens on exposure to the air; but in some places are beds that receive a tolerably good polish. Its conglomerate beds are very cavernous; an instance of which is Wookey Hole, Somersetshire, inferior only to the caverns of Derbyshire.

The highest points of the principal range are generally in round topped hills; they are the most elevated at the two extremities but do not much exceed 600 feet above the sea-level. It overlies the 90 fathom dyke, which intersects the Northumberland coal field; hence it is concluded to be posterior in formation to that dyke, which is, itself, posterior to the coal. Its beds form an aggregate thickness of about 300 feet, and rest upon the sandstone or shale of the coal measures. Its general dip is in a south easterly direction; but is not much above 40 feet in a mile. Small veins or strings of galena and also of Sulphate of Barytes are found in it both in Durham and Nottinghamshire; and in the conglomerate beds are fragments of ore from the Pennine rocks. The few organic remains are almost invisible, being chiefly marine shells and a few impressions of fish;—but they somewhat differ from those of the older formations.

Much of the Alpine limestone is referred by geologists to this formation, as also that of the mercurial mines of Idria. In short it seems to be of much more importance on the continent than in England—exhibiting mountains plentifully interspersed with gypsum, which is not often found in it in Britain. It also occurs among the Andes, where, as well as among the Alps, it is metalliferous.

The New Red Sandstone. This formation is sometimes a reddish clay, which frequently contains calcareous matter when it becomes marle; it is sometimes a sandstone, which occasionally assumes a slaty texture; and, at other times, it consists of beds of water worn pebbles, or agglutinated fragments of all the older rocks. The red-marle or clay beds generally occupy the highest strata, the sandstone the middle, and the conglomerate the lowest:—and where these basset out, they give the prevailing character to the soil on the surface.

The *patches* of gravelly soil, that prevail near the junction of the new-red-sandstone formation and the magnesian limestone, are the basset edges of this *conglomerate.* These beds often extend over extensive tracts, as at Sherwood forest, where they form the prevailing stratum. They are often consolidated into a pudding-stone, as in the Castle-hill at Nottingham: or a breccias as in the neighbourhood of Exeter. They are in places not less than 200 or 300 yards thick.

The *sandstone* consists of fine grains of quartz, and a few specks of mica cemented by clay and oxide of iron. It some-

times contains small, white, opaque crystals of feldspar, and at one place near Exeter, it graduates into amygdaloidal trap. It occasionally affords a tolerably good white freestone, used for building; but the red kind, though it does not resist the weather, is much used. Where it crops out, it forms large tracts of variously coloured sand.

The *marle* and sandstone vary in colour from chocolate to red and salmon, frequently exhibiting streaks of light blue, verdigris, buff or cream colour. The red marle is remarkable for its fissures, which are transverse to the strata, and separate the rock into rhombic forms. In some places the rock is split into basaltiform balls.

Gypsum, sulphate of lime, if crystalline *selenite,* and if granular or fibrous *alabaster,* chiefly occurs in the red marle; but at Newbiggen, Cumberland, it lies between two strata of sandstone, and in some places it rests on decayed wood like umber. It is found in almost all districts of this formation, but seems to occur in particular patches or nodules, where it occasions a rise or isolated hill by its additional thickness; but it is frequently met with in thin beds, sometimes finely striated transversely to the strata. The pure white is used for plaster of Paris, the alabaster for ornaments, flooring, or common walling stone.

But the most important mineral of this formation is the *Rock Salt,* which is found chiefly in the red marle. It occurs principally in Cheshire where are many salt springs yielding 25 per cent. At Northwich are two beds, together not less than 60 feet thick, forming an area of more than a square mile. There are also two others at no great distance: the upper one 75 feet thick; and the lower has been sunk into 108 feet without perforating it. But the salt mines in a mountain near Cracow in Poland are the most extensive in the world. Near 1000 workmen are continually employed in them, and they have been worked near 500 years. The excavations are made with great regularity. Pillars of pure salt are left to support the roof; and these, like so many columns of alabaster or diamond, reflect and refract the light, and give indescribable beauty to the whole. The same may be observed of the mines in Cheshire.

In the year 1820 a rock of salt of 30 square leagues and of an immense thickness was discovered at Vich, department of Meurthe, France. There are four sorts, white, half-white, grey and red:—it does not deliquesce. At Cordova in Spain is a salt mountain of 4 or 500 feet elevation, and 3 miles in circum-

ference. In above 200 places in Transylvania and Moldavia are salt mines. In Caramania, and at Ormuz in Persia, the atmosphere is so dry, that it is used as building stone. In Peru a rock of salt, of a purple colour, is found 900 feet above the sea-level. But in Louisiana near the Missouri, is the most extensive mountain of salt hitherto discovered. It is 80 miles long, 45 broad, and of an immense height.

The New-red-sandstone seldom rises more than 300 feet above the sea-level, except in one instance where its height is 803 feet. Its thickness is considerable. Between Darlington and Yarm, near its junction with the magnesian limestone, it has been bored into in search of coal 708 feet without perforating it. Near Evesham, Worcestershire, it was sunk through 600 feet in a like fruitless search. But in Glocestershire, where it is overlaid by the Lias, coal has been found beneath it, and its thickness was only 153 feet. However its thickness near the river Tees cannot be taken at less than 700 or 800 feet; to which perhaps we may add 300 more for the magnesian limestone; and if the coal measures extend thus far, which is very doubtful, the seams will not be perhaps at less than from 200 to 400 feet below that: so that coal cannot be at a less depth from the surface than from 1000 to 1500 feet.

Its mineral contents are a few fragments of ores from the debris of the older rocks; but it abounds in mineral waters. As Hartlepool, and Middleton, *Durham*. Croft and the water of a pump two miles westward of it. Knaresborough and Ripon, *Yorkshire*. Gainsborough, *Lincoln*. Moreton, *Shrops*. Orston and Thoroton, *Notts*. Lemington and Newnham Regis, *Warwick*. Tewkesbury, *Glocester*., and some others.

As the New-red-sandstone was the winding up of the great catastrophes, which principally remodelled the earth's surface; so it is the most extensive of all the formations. It abounds in central Europe, skirting both sides of the Carpathian chain; and is supposed to form the sandy deserts of Asia and Africa, and a great portion of the American plains;—however the proof of its identification seems to rest principally on the presence of rock salt.

The formation of rock-salt, and its seeming peculiarity to this sandstone, is one of the most difficult problems in geology. Two solutions of it present themselves.—*One*, that it was ejected from the earth nearly in its present state. The objection to this supposition, is, its not being associated with rocks older

than the new-red-sandstone. But, if the sea washed over the older formations it might dissolve and remove the salt; while those few masses which now remain in the new-red-sandstone might escape by their being formed in lakes, or at points from which the sea subsided in each direction. The *other* solution, is, that rock-salt was disposed in its present state by the evaporation of the sea water. Suppose a volcanic heat to be emitted from the bowels of the earth, through some parts of the ocean not much agitated by the tide, and this volcanic process to continue through the course of a few centuries, without any ejection of earthy matter. Such a heat would decompose the water of the ocean, and send it off in steam;—but in such a process the salt would be left behind. If we suppose such a process while the new-red-sandstone formed the bottom of the ocean, we may perhaps have some idea how the rock-salt was deposited.

12. THE OOLITIC SYSTEM.

We are now entered upon a new order of things; and instead of contemplating the result of dreadful concussions of the earth's subsiding surface, and the emission of such quantities of caloric as fused the solid materials; we shall henceforth be occupied with what we may suppose would be floated to a distance by the receding ocean, and deposited on shores far from the scene of volcanic action. At this period, therefore, we are to suppose the rocks we have been describing with others of the same kind, as constituting the whole of the dry land;—with the ocean sweeping over all or chief part of the now external surface of the new-red-sandstone. Supposing the dry land at that time to have borne the same proportion to the surface of our planet, that it does at present; as portions of the primary and transition rocks subsided below the level of the sea, the volcanic matter emitted, and the diluvium swept off the now emerging formations, would form a deep deposition at the bottom of the ocean. According to this hypothesis, a part of the oolite system would be thus deposited, while the magnesian limestone formed the shores of the ocean.

Now as volcanoes have their periodical seasons of activity, we are not to suppose that these subsidences occurred either simultaneously, at regular intervals, or with uniformity of extent. The new accessions of matter, therefore, to the bed of the ocean, would take place after irregular intervals, and, as to

quantity, with every variable proportion. We shall consequently have strata of all degrees of thichness, with alternations of every variety of materials. And as these new accessions would overwhelm the inhabitants of the deep, we shall therefore have intervening strata almost entirely composed of marine organic remains, others with only few, and others destitute. And as a subsidence would extend occasionally to the shores of the ocean, and thus commence a new formation, while another subsidence took place at a short distance from the former, and extended across both the recently commenced formation, and the one on which it was deposited, this would give rise to another new formation which would overlie both the recently commenced one and the older; the oldest of the three would therefore come in contact with the newest;—or, the middle one would thin out and be wanting. In this manner are rocks of the latest formation brought in contact with the oldest rocks. Instances of this kind are not wanting through all the formations. The old-red-sandstone, in the Western Isles, comes in contact with gneis, or granite; the inferior oolite in Somersetshire with the old-red-sandstone; and, on the continent, the chalk, with some of the coal measures; with numerous other instances.

With the exception of the Cleveland Dyke, and the Basaltic range of the Giant's Causeway, no trap formations, at least in the British Isles, are found among the rocks we have now to treat of. Neither are there any metallic veins in them:—but as they all contain breccias or conglomerate beds composed of fragments of the older rocks, generally rounded by attrition into pebbles, so they frequently contain specimens of ores:—such as galena, blende, sulphate of barytes, and sulphate of strontian, and occasionally other specimens. Martial pyrites are very common, and in nearly all the oolitic system, strata of clay-iron-stone are found; and particles of iron oxide are dispersed throughout nearly all the strata. When it is in the state of red or peroxide, it gives a dirty brown colour to the stone; but it is as often in the suboxide, when the stone has a greenish cast.

With the Lias a new order of organic remains commences, and continues, generally, throughout the oolitic system, and ends with the chalk. They consist of "corals, encrinites, echinites, testacea, crustacea, vertebral fishes, and marine oviparous quadrupeds, yet widely distinguished from the families

contained in the lower beds of the transition and carboniferous class, and partially distinguished among themselves according to the bed which they occupy. But the various species may be found with nearly as much readiness and certainty in the natural strata, as in the drawers of a well arranged cabinet."

The oolitic system divides itself into three distinct ranges of hills of considerable elevation, though much inferior in this respect to those of the older formations. Each range has an aluminous series for its base, which seems, while it formed the bottom of the ocean, not to have indurated like the sandy and calcareous series. Consequently, when the ocean was drained off by a distant subsidence, a great deal of this aluminous formation was swept along with it, and thus left the cemented calcareous sandstone a range of rocks, with a ragged precipitous edge or escarpment. In this manner was the Lias probably scooped out and swept off with some of the red-marle, so that the calcareous sands of the inferior oolite were left at a considerable elevation, above the adjoining plain; which, otherwise, we suppose might have been nearly level.

The Lower Oolitic Series, comprising the Lias, the Inferior Oolite, the Great Oolite, Bradford Clay, Forest Marble, Stonefield Slate, and Cornbrash.

Lias.—The principal component ingredients of this formation are alumina, lime, and iron. It consists of three series of beds. The lowermost, resting on the red-marle, contains several strata of black and blue marle, with intervening strata of clay-stone, forming sometimes concretional and rubbly masses, and sometimes merely very thin layers of clay. The middle series, called the *true Lias beds*, contains a number of thin limestone strata, separated by narrow argillaceous partings, so that the quarries at a distance present a striped and ribband like appearance; in the lowermost series these partings almost disappear. The uppermost series, which constitutes about two-thirds of the whole formation, consists chiefly of beds of deep blue marle, containing only a few irregular and rubbly limestone beds. The whole formation is about 4 or 500 feet thick.

The most perfect limestone contains about 90 per cent. of carbonate of lime, the rest is alumina and oxide of iron, with occasional traces of silica, though this earth is very rare in the Lias. Its colour in different beds varies from light slate blue

or smoke grey, to white;—its aspect is dull and earthy, and its fracture conchoidal. The blue, which contains the most iron, makes a strong cement that sets under water; the white takes a high polish and might be used for lithography. The clay-stone is grey, brown, or black; is sometimes bituminous, and separates into laminæ. Some of the beds of Lias are used as building stones, slabs; and in some places, as in Warwickshire, it is worked into chimney pieces as marble. The Cottom-stone is dendritical. The iron and clay stones are used for making Parker's cement. They seem to have had a cornu ammonis, or some other small organic substance, as a nucleus around which they formed, and are not unfrequently coated with pyrites, blende or galena. Near Whitby are masses of iron-stone that yield from 30 to 60 per cent. of oxide of iron; the rest is, phosphoric acid, lime, alumina and silex. It is smelted at Newcastle.

Martial Pyrites are so plentiful where this formation is exposed along the Yorkshire coast, that it is supposed the sulphur, when in contact with moisture, has quitted the iron and formed a chemical combination with the alumina, whence the aluminous schist, or sulphate of alumina so extensively worked for alum. Where these pyrites come in contact with moisture, spontaneous combustion ensues: as in the cliffs near Charmouth; and in some masses, fallen from the precipice near Whitby, washed by the tide, and which continued in a state of combustion two or three years.

Among the most noted organic remains in the Lias are the cornua ammonis, ammonites, or Whitby snakes. They are the silicified shells of a certain fish nearly allied to the nautilus. Of this remarkable fossil there are enumerated about 200 species, some of which are three feet in diameter; yet there is but one species now existing, of not more than about half an inch in diameter. We now meet with remains of animals of a higher order. The first are two extinct genera of a kind of lizard, or crocodile, the Icthyosaurus and Plesiosaurus, of a size approaching the whale different from any thing now known to exist, and which seem to have been entirely confined to the water. The vegetable remains consist of jet, silicified wood, gigantic reeds, ferns and flags.

The Lias forms the lower and principal part of the cliffs between the Tees mouth and Whitby. It hence stretches in a very regular course to a few miles south of Gloucester, with an

average breadth of 6 miles; it afterwards has an irregular feather-like course, reaching with a few slight interruptions to Lyme on the boundaries of Devonshire and Dorsetshire. Thence across the British Channel to France. It is also found at the south-east point of Wales. The most elevated parts seem never to exceed 500 feet above the sea-level. Indeed it is more remarkable for forming broad and level plains at the foot of the oolitic chain, a little elevated above the red marle tracts. But these plains are frequently diversified with low ridges, and slight escarpments, as in the Wold Hills of Nottinghamshire and Leicestershire.

The following mineral waters seem either to rise out of the Lias or to be connected with it:—Ilmington, Cheltenham, Bath, Glastonbury, and Alford, near Castle-Cary.

The Inferior Oolite.—This series, in the neighbourhood of Bath, is separated from the Lias by beds of corals and shells in the argillaceous formation that covers the Lias. It consists of three formations. The *lowest* a calcareo-silicious rock, upwards of 50 feet in thickness, and used for mending the roads. In some places it is gritty and micaceous, and coloured with the oxides of iron. The thickness of the *middle bed,* or inferior oolite proper, is about 30 feet. It is a kind of freestone (calcareous sandstone). The upper part is hard and used for the roads; the lower is squared for building. It abounds in globular particles of oxide of iron, which cause the beds externally to have a brown cast:—but internally they have a blue or grey tinge. The *uppermost* series is principally a bed of an inferior kind of fuller's earth 100 feet in thickness, with a thin rock in the middle of tolerably good road-stone. It is succeeded by 8 feet of good fuller's earth; and then by 12 or 15 feet of blue clay; and this again by the same thickness of yellow clay. In different parts of the island these beds seem to graduate into each other.

The Great Oolite or Roe-stone. This both in thickness and utility, is a very important formation. It consists of a stratified calcareous mass, varying in thickness from 130 to 200 feet. Softer and harder strata alternate;—the former having principally the *oviform* or *roe-like* concretions whence the system derives its name;—it is this also that renders the oolite so valuable as a freestone. That of Kettering, Northamptonshire, is instanced as a fine specimen of the oolitic structure; and that of Bath is noted for its fine grain. The latter was employed for the late repairs of Henry VII Chapel, Westminster. St Paul's

was principally built from quarries about a mile north of Burford, Oxfordshire. Its colour is generally white with a yellowish cast. Some of the beds are grey, some almost blue in the middle, and sometimes, near the fuller's earth, there are interposed beds of a brown ferruginous cast. The *freestone* is in thick bedded masses, which usually thin out at a distance. Many of the other beds exhibit a laminated cleavage, not parallel to the line of stratification. Fragments of comminuted shells may be observed mingled with the ova; and in the Cotteswold hills, traces of magnesia are found in the lower beds; but the almost sole ingredient of the oolite is carbonate of lime.

The Bradford Clay consists of common blue marly clay, of the thickness of 40 or 60 feet, sometimes separating the great oolite from the forest marble:—where it is absent, these two formations imperceptibly graduate into each other. It abounds with organic remains differing from any we have yet met with.

The Forest Marble is a slaty kind of limestone, lying between beds of calcareo-silicious sandstone, and gritstone: the whole formation is generally fissile, and divided by clayey partings, and contains about one-third lime. The marble seems to consist of a congeries of dark coloured shells interspersed with whitish oolitic particles. Its beds are generally thin and slaty; the thickest being only two or three feet. It affords a coarse roofing slate, and the more solid beds, receiving a tolerably good polish, and being variegated with its imbedded shells, are worked as a coarse marble. Its colour is grey or bluish;—though some of its joints have a reddish tinge occasioned by the presence of decomposed pyritical wood.

The Stonefield Slate consists of two beds of greyish oolitic limestone called *pendle*, each about two feet thick, separated by about two feet of the above limy sandstone, which here contains circular concretions of slate, called *Whimstones* or *Potlids*, that separate into plates. In some places, these formations and the great oolite seem to pass into each other; and they are overlaid by a bed of from 8 to 14 feet thick of blue clay, which in the upper part is white.

The Cornbrash is a loose rubbly limestone of a bluish colour; it is constantly attended on its surface by a red soil. It is only used for lime and the roads except at Malmsbury, where it is thick and solid, and quarried for building.

Among all the oolitic system are occasionally interspersed quartz crystals, and stalactic calcareous spar. The beds above

the great oolite present fine specimens of the latter, which are in bright, transparent yellow and sometimes beautifully radiated and plumose crystallizations. In these beds also, but particularly in the Stonefield slate, we have the most singular assemblage of organic remains that is perhaps to be met with in this branch of natural history;—comprising, land animals, birds, insects, amphibia, fishes, shells, and vegetables. They are imbedded in the slate, and not in its fissures. The animal bones are supposed to belong to a species of the opossum tribe. A crocodile of a species differing from all others known of, was found in the cornbrash, and is now preserved in the University of Oxford. An immense animal, similar to the monitor occurs at Stonefield; some specimens indicate a length of 40 feet and a height of 12. In the same calcareous slate are also found two or three species of tortoise; teeth, palates, and vertebræ of several kinds of fish; the legs and thigh bones apparently of birds; two or three varieties of the crab and lobster; and a few different species of insects. All these, together with abundance of shells, (that sometimes seem to be the chief ingredient of the rock), enter into the component material of all these formations. In all the beds, particularly the forest marble, fossil wood may be traced. At Stonefield are many beautiful vegetable impressions, nearly resembling those of the coal formation, chiefly ferns, flags, and mosses.

The lower series of the oolites forms the mass of a well defined range of hills, traversing the island diagonally from the Yorkshire coast to that of Dorsetshire. The eastern side being skirted by the Oxford clay, and the lower part of that declivity principally formed of the cornbrash, which is succeeded in the ascent by the forest marble, and calcareous slate, from beneath which emerges the great oolite that forms the summit. The western declivity is composed of the inferior oolite, based by the lias. The most noted elevations are the Cotteswold in Gloucestershire, and the Hamilton hills in Yorkshire. Meon hill, an outlier of the Cotteswold, commands one of the most extensive prospects in the island. The whole of the western range, especially towards the Severn and Bristol channel, presents a number of conical knolls, that seem fragments of the inferior oolite, the rest having been washed away with the lias. Roseberry Topping, Yorkshire, capped with the inferior oolite, is one, and the most elevated, being 1022 feet above the sea-level. But around Bath, the inferior oolite generally forms low

terraces, capped with the great oolite. Dundry Hill, three miles south of Bristol, rises 300 feet above the Lias that supports it, and 700 above the sea. The oolitic range is the most elevated in Gloucestershire. The loftiest point is Cleve Hill, near Cheltenham, 1134 feet. In some parts of Somersetshire, coal has been found at only about 200 fathoms beneath the surface of the inferior oolite; but at any other place it cannot be at less than 3 or 4 times that depth.

The whole range is much broken through by valleys, in which are the rivers that have their rise among them, and take their superfluous waters to the ocean. The Bristol channel must have subsided after the formation of this series; consequently, in the neighbourhood of the Æstuary of the Severn, the strata display the utmost confusion, and are at all inclinations. The subsidence which gave birth to the weald clay, that introduces the chalk series, must have extended to the lower system of oolites, depressing that part which now forms the channel of the Humber, skirting northwards towards Kirby Moorside, and then easterly towards Filey Bay. At this time was most probably formed the caves and fissures lately discovered in this part of the oolitic range at Kirkdale, containing a number of organic remains, but which are totally different from those that we have described as imbedded in the rock.

The Middle Oolitic Series, consisting of the Oxford Clay, and Coral Rag.

Oxford or *Clunch Clay,* consists of immensely thick beds of tenacious, adhesive, dark blue clay, mixed with lime. It sometimes contains bituminous matter, affording an inflammable shale, that has often caused useless attempts for coal. Argillo-calcareous geodes and septaria, frequently called *turtle-stones,* occur in this formation. Also towards its lower part irregular beds of limestone, called the *Kelloway rock,* are found, apparently consisting almost entirely of organic remains, in which the ammonites predominate; but, on the whole, the fossil species are peculiar. This formation is supposed to constitute the substratum of the fens of Lincolnshire, and also of the western border of those of Cambridge and Huntingdonshire:—hence it has sometimes been called the *fen-clay.* It constitutes the vale of the Ouse in Bedfordshire, as also that of the Isis for several miles south-west of Oxford. But though it generally

forms the lowest surface of the island, yet it sometimes swells into gentle eminences, as near Malmsbury, Trowbridge, and north west of the vale of Blackdown. Its average thickness is from 500 to 700 feet. The following purgative springs are in it:—Stanfield, *Lincoln*. Kingscliff, *Northampton*. Cumner, *Berks*. Melksham and Holt and Seend, which is iron and carbonic acid, *Wilts*., and Somersham, (green vitriol) *Hunts*.

The Coral Rag constitutes a well marked range of hills between the Oxford and Kimmeridge clays, and consists of three distinct beds, each containing several strata: the whole being about the thickness of one or two hundred feet; and the average height from four to six or seven hundred feet above the sea-level. The *lower* bed consists of *calcareous grit*, being a yellow, quartzose sand, containing about a third of calcareous matter; and it is traversed by strata of a gritstone of nearly the same composition. This grit contains more organic remains than any other strata of the formation. The *middle* bed is peculiarly stiled the *coral rag*. It consists of a loose rubbly, but sometimes marly limestone, chiefly composed of branching *madripores*—the madripores nearly disappear with this formation. There are, besides, two or three irregular strata of a grey colour. It is only used for the roads, The *uppermost* bed has somewhat of the oolitic character, is a calcareous freestone of a close texture full of very small fragments of shells, and forms a tolerable, but not a very durable, building stone. It is a good limestone, containing only from one-tenth to one-third sand. It is sometimes called *pisolite*, and the *superior* or *Oxford oolite*. Oxford is chiefly built with it.

The Upper Oolitic Series, comprising the Kimmeridge Clay, the Aylesbury, Portland, and Purbeck limestones.

The *Kimmeridge* or *Oaktree clay* consists of beds of slaty, blue or greyish yellow clay, yielding in some places, as near Kimmeridge on the coast of the isle of Purbeck, highly bituminous beds of shale used as fuel. These slaty beds contain both animal and vegetable impressions. The upper part of the rock is covered with calcareous spar, and the upper part of the shale with martial pyrites; hence the shale burns with a yellowish flame and sulphureous smell, but the lower part, called *stony coal*, seems to contain no sulphur and burns freely;— it contains a little lime. Selenites occur in it, also sulphate of alumina

from which alum has been made. Its greatest thickness seems to be about 700 feet.

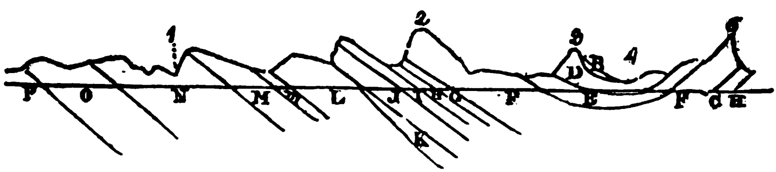
The *oolitic* strata of Portland, Tisbury, and Aylesbury are a coarse, earthy limestone; consisting of various beds differing from each other, and even from themselves in different places: indeed the calcareous rocks through all the oolites are hardly distinguishable from each other except by their organic remains.

The stone, chiefly used for architectural purposes in London, comes from the more oolitic part of this formation in the isles of Purbeck and Portland. The lower beds of the latter place contain numerous casts of shells; and these beds alternate with others consisting of chert; the next superincumbent beds are worked for sale; and the uppermost, or *cap*, is principally burnt for lime. The whole are about 120 feet thick. But the thickness of the Purbeck beds is about 300 feet. They consist of many thin strata of argillaceous limestone, alternating with slaty marles. The lower beds of stone consist chiefly of broken shells in a pure sometimes crystallized calcareous cement. Those beds are separated by others without shells, also by shivery layers of shale and marle. The upper beds, called the *Purbeck marble*, have the shells more entire, and their calcareous matter more pure. The columns and monuments of the Gothic churches were made of it, but it is now out of use, and its quarries are filled up.

The British channel must have subsided after the deposition of these formations; consequently, about the isles of Portland and Purbeck, where they are principally developed, the strata are in the greatest confusion, being broken, arched and contorted in the same manner as the transition slates. At Chilmack, Fonthill, and Tisbury the strata dip towards the north and east, with an angle of 40 degrees. In the isle of Purbeck they dip inland from 45 to 60 degrees. The elevation of Portland and Purbeck is about 300 feet, but on the borders of Oxfordshire and Buckinghamshire, they are considerably more elevated. It is not known whether any of this upper oolitic system, or even the middle one, extends into Yorkshire; and some of the strata are deficient in the southern parts of the range.

None of the oolitic series are found in any other parts of the British Isles, except the Lias which occurs near the basaltic district, in Ireland, in the isle of Sky, and in some other of the Hebrides. As we consider them to form a part of the

contents of the great European basin, of course, they are to be found in France, encircling, at least in a great many places, the chalk district. They principally compose the Jura chain, and abound among the Alps and throughout all Europe. Humboldt also speaks of them among the Andes. The following *cut* represents a vertical section of them and the succeeding formations, taken from a few miles south of Leicester, to between Guildford and Ryegate in Surrey.



P. The New-red-sandstone. O. The Lias. N. Inferior Oolite. M. Great Oolite. *m* Cornbrash and Forest Marble. L. Oxford or Clunch Clay. K. The Coral Rag, Calcareous Grit, and Kimmeridge Clay are wanting. J. Aylesbury or Portland Limestone. I. Iron Sand. H. Weald Clay. G. Chalk Marle and traces of Green Sand. F. Chalk. E. Plastic Clay. D. London Clay. B. Upper Marine. 1. Northampton. 2. Chalk Hills near Ivinghoe 904 feet elevation. 3. Harrow on the Hill. 4. Bed of the Thames. 5. Botley Hill 886. The horizontal line is the sea-level.

13. THE CHALK SYSTEM.

THE Great Chalk formation is separated from the last of the oolitic systems, by a series of beds called the *Iron-sand*, the *Weald-clay*, *Green-sand* and *Chalk-marle*,—being altogether about 1000 feet in thickness. However, with the exception of the iron-sand, which may be considered as the winding up of the oolites, they, together with the great chalk formation, may be as strictly said to belong to one system, as the component beds of any one of the three oolitic systems. The Weald-clay may be compared to the lias; the green-sand to the sandy beds between the lias and the inferior oolite; and the chalk-marle to the inferior oolite and its beds of fuller's earth; while the chalk itself with its flints will bear a comparison, as to component ingredients, with the great oolite, forest-marle, cornbrash, &c. Should we refer to the chronological indices, viz. the organic remains, we perhaps may find an equally near analogy. But though the chalk system contains the same elementary ingredients as the oolitic; yet, there seems to have been a considerable difference in ths process of deposition. In the oolites we find the lime generally combined with the sand, for which it is well known to have a great affinity:—in the chalk system they are uncombined; and the lime seems to have been deposited in the form of chalk, while the silica was afterwards precipitated around organic remains, and in the fissures of the chalk. Hence the origin of flints which are so abundant in the chalk formation, and which are mostly found to have had a sponge, an alcyonium or piece of wood for the nucleus. It is difficult to account for this difference between the chalk and the oolite, only we would remark that the calcareous matter of the latter is chiefly comminuted shells, while the chalk exhibits nothing but a uniform texture of unorganized carbonate of lime. The oolite then may have formed the bed of the ocean, mixed up with organic remains, and indurated by the stalactitic process; while the chalk, (as recent volcanoes have emitted fluid chalk) might have been ejected from the volcanoes of a vast subsidence and merely floated to its level by the ocean.

Iron-sand, carstone or *quernstone* consists of a series of strata, in which sand and stone predominate, and sometimes alternate with subordinate beds of clay, loam, marle, fuller's earth, and ochre. The stone is composed of silica and the red oxide of iron;—the latter is occasionally so abundant that it was formerly

much in request for smelting,—it gives a brownish red aspect to the soil, or where less abundant the beds are yellow or a light buff. In some places the stone is a very coarse conglomerate, but in others a fine grained sandstone. At Horsham, Sussex, it yields flags for paving; near Lynn in Norfolk the iron-clinkers are valued as building stone, and it is used as such about Tunbridge. At Farringdon, Berks, it is used for mill-stones, and in Wiltshire the ancient Britons got from it their quernstones. It contains fossil wood, and even in places, as at Lulworth Cove, Dorsets, regular beds of wood coal. The alternating sand has also the appearance of that of the great coal formation. In Surrey it contains a thin bed of vegetable, and occasionally carbonaceous matter. At Aspley and Crawley occurs silicified wood, and not far from the former place are pits of fuller's earth. Specimens of hæmatitic and stalactitic iron are found in the ochreous beds. Its thickness is about 500 feet, and its most elevated point is Brill hill, where it caps the Purbeck beds. The chalybeate waters of Tunbridge are in it.

The *Weald clay* containing the *Petworth marble.* This formation varies from a dark, tenacious clay, to a blue or grey marle. It generally contains layers of argillo-calcareous concretions, full of shells of the genus vivipara *fluviorum*, the middle of which is usually filled with calcareous spar:—this is the Petworth marble. It partly resembles the Purbeck marble, with which it has been confounded. The taper shafts clustering round the columns of the early gothic style were made from the latter, while the Petworth marble, on account of its brittleness, was merely wrought into thick slabs. Some quarries are still worked in Surrey. Many of its beds contain specks of mica, and sometimes nodules of iron pyrites and selenite; but this formation has not received much attention, and therefore its organic remains are little known. It is exhibited on the largest scale in the Wealds of Kent, Surrey and Sussex—whence its name. It is here about 300 feet thick, but in the Isle of Wight its thickness is only 100 feet. Where springs of water come in contact with the blue marle, it becomes of the consistency of mud, runs out, and leaves the overlying sandstone without support. A large landslip in the Isle of Wight, now variegated with rocks, woods, cottages, and cornfields, and which forms the principal attraction of the visitors to the island, is partly attributed to this circumstance.

The *Green Sand.* This is the most important of these formations both in extent of surface, and in the number and beauty of its organic remains:—though its greatest thickness is supposed to be only about 300 feet. It consists of loose, pure sand and sandstone that has a calcareous cement. Spangles of mica occur in it, and in some places, beds of chert and veins of chalcedony. It frequently alternates with beds and nodules of limestone, called *rag;* and occasionally beds of clay, and fuller's earth are found in it. Its texture varies very much in different places, from a quartz conglomerate to a fine grained sandstone. Its green particles are occasionally so abundant as to form its prevailing colour, but sometimes the iron is in the red oxide, when the colour is buff.

In Devonshire and Dorsetshire a patch of the green sand comes in contact with the new-red-sandstone, so that the subsidence, which depressed this part of the island, must have been posterior to the oolitic system, and must have given birth to this formation. It here crowns many hills, among which is Blackdown; its thickness is 200 feet; and it is in the form of a fine grained sandstone, and principally supplies England with whetstones—its quarries yield 150 species of shells. Its elevation here and at Halidon, beyond Exeter, is 818 feet; but at Leith, in Surrey, it is 993 feet

The Chalk-Marle is a mere connective link formed by the gradation of the green-sand into the chalk. Its lower beds are, therefore, principally sand, its upper chalk, and the middle are of an argillaceous character. Yet the component ingredients are so intimately blended through all the beds, that the subdivisions are no better to distinguish than the limits of the formation. The lower beds are a fine grained, greyish sandstone of a loose texture; the middle are a bluish grey marle, and the upper are distinguished from the true chalk by their greyish or mottled character, laminated texture, falling to pieces after being wetted and dried, and not marking like chalk. In some places they assume such hardness as to be used for building stone. They contain about 82 per cent. carbonate of lime, while the middle beds only contain about 30. The thickness of the whole formation is about 300 or 400 feet. The most elevated point is at the old Roman station called Sinodunum, which overhangs the Thames opposite Dorchester 600 feet above the sea-level. It is extensively quarried at Totternhoe

(Beds.,) and Reach, (Cam.,) where it is called clunch. It forms the Castle-hill at Cambridge, and most of the neighbouring heights;—thence ranges by Royston, Balsham, and Newmarket.

The Chalk Formation. Chalk consists of 56·5 lime, 43 carbonic acid, and 0·5 water. It is generally white, but its less pure varieties sometimes contain a tinge of alumina or silica, when the colour is yellowish; some of the lower beds are of a reddish colour, and are supposed to contain red oxide of iron. Throughout the formation, but especially in the lower beds, are specks of green earth, the same as in the green sand. Near the bottom, harder beds alternate with the soft upper ones. These afford a compact and very durable building stone, as witnessed by the Abbey of Hurley, Berks, and with which the harbour at Dover is now constructing: its blocks return a ringing sound to the blow of a hammer.

It occasionally contains subordinate beds of other substances, as chalk-marle, fuller's earth, and thin parting seams of clay; but its most remarkable feature, is, its beds or layers of nodular flints, which alternate through the greater part of its mass, though much more abundantly in the upper part;—hence the distinction of the *upper* and *lower* chalk. Sometimes the flinty strata consist of tabular masses, which are occasionally in veins. Near Brighton is a bed containing flints and rounded masses of granite and porphyry. The only mineral in chalk is martial pyrites. They are mostly crystalline, exhibiting, when broken, a fibrous structure; and are often in a cylindrical form,—these were once supposed to be thunderbolts. Near Warminster, Wiltshire, large blocks of crystalline carbonate of lime have been found.

The organic remains, which have hitherto attended us, entirely cease with the chalk,—they being very different from those that occur in the later formations. These in general may be identified with what now exist in the neighbouring oceans; while all those in the chalk and downwards, belong to extinct species; and many of their genera, which on the whole are comparatively few, are different from any now known. The ammonites, which are here from 12 to 18 inches diameter, end with the lower chalk. Nearly all the flints, after they have been steeped in water, exhibit the appearance of silicified organic remains. Their interior often contains drusy cavities lined with tubercular chalcedony or quartz crystals. It exhibits

other traces of organic remains, whose original substance is replaced by carbonate of lime; at other times by martial pyrites.

The general character of the surface of the chalk is hilly;—the hills being remarkable for their rounded outline, and for the deep hollows and indentations on their exterior side, and their interior gentle slope towards the centre of the formation, when, at the distance of some miles, they glide beneath the plastic clay. It is also remarkable for being broken through by rivers that have their rise on a surface of far less elevation. At the conclusion of this formation, nature seems to have made a considerable stand, before she overlaid the plastic clay; since the surface of the chalk, when stripped of this clay, displays, by its indentations, a long series of the action of floods; and it contains many deposits of alluvial and diluvial beds of its own flints, that have been washed out of it. Indeed, over a great many counties westward of the chalk are traces of it, as if it had been completely washed away with the exception of some round hard fragments and some of its flints. Yet this might have been occasioned by one of those subsidences, which have depressed the British part of the great European basin so much below the Alpine edge; when the sea again broke over the oolitic systems, and thus carried the fragments of the chalk formation far from their bed; at the same time giving the determination to its transverse valleys.

The chalk is considered as forming the best ascertained stratum of the central European basin, extending from the Thames on the west to the Don at the eastern limits of Europe, and next to the new-red-sandstone, displaying the most extensive surface: though it is doubtful whether it exists beyond Europe, and it is positively affirmed that it is nowhere to be met with on the American continent. Its average thickness is supposed to be from 600 to 1000 feet. It constitutes the Wolds of Yorkshire and Lincolnshire, where it has an average breadth of rather more than six miles. Its greatest elevation in Yorkshire is at Wilton Beacon 809 feet. In passing through Bedfordshire, it forms the Royston and Luton Downs; and in Buckinghamshire and Oxfordshire are the Chiltern hills. The vale of the Thames passes through it, where is the finest natural scenery of that river. It thence takes the name of Ilsey downs, Whitehorse hills, Marlborough downs; Inkpen hill south of Salisbury is its highest point, being 1011 feet above the sea-level;—it

here forms a principal part of Salisbury plain. A branch of it forms the north downs of Surrey and Kent, bounding what is called the London basin on the south, and ending in the cliffs of Dover, which range along the coast about 13 miles, and at a mile north of Folkstone have an elevation of 575 feet. Another branch forms the South downs, skirting the Wealds through Sussex, and ending in the promontory of Beachy head.

The chalk, since its deposition in horizontal beds, has been disturbed by many distinct subsidences, apparently occurring at different æras: hence, its strata are variously inclined. Where it exhibits no signs of great disturbance the dip is very gentle, being in Yorkshire, near Hull, only 5 yards in a mile eastward. But near the subsidence which separated the Isle of Wight from the Hampshire coast, the chalk is vertical, as at Culver cliff in that island, also on the opposite coast near Purbeck. The same subsidence probably extended along all the southern coast; for, where the outlying chalk and green-sand formations come in contact with the lias and new-red-sandstone, the chalk cliffs on the shore from Lime to Sidmouth exhibit vertical strata. In the *South downs*, the dip towards the Isle of Wight basin or subsidence is from 5 to 15 degrees. In the *North downs*, where the inclination was caused by the subsidence which gave birth to the London basin, the dip is from 10 to 15 degrees; from Guildford to Farnham Surrey it is 45 degrees; but ranging round by the west to the south, the dip is very gentle. At Dover the dip is less than 1 degree towards the N. E.

The opposite coast of France affords a curious subject for speculation in the subsidences which have disturbed the general outlines of the great European basin, and severed England from the continent. We have there along with the oolitic system a portion of the mountain limestone, while the corresponding English coast displays nothing older than the iron-sand. And the cliffs of Dover or Folkstone seem to be near double the height of those on the French coast. The English coast must therefore have had a lower level than that of France at the commencement of the oolites, but after the deposition of the Plastic clay, the French coast must have subsided; while that of England from Dover to Beachy head must have nearly retained its position :—at this time we suppose the sea broke through the straits of Dover; and as the English strata shew no inclination

towards the centre of the straits, probably these lofty cliffs owe their precipitous character to a *slip*.

In Surrey the river called the Mole has its subterranean course through the chalk formation, though but a small part is engulfed or absorbed, except in long droughts when the whole disappears for a space of two miles.

14. STRATA ABOVE THE CHALK.

Plastic Clay, London Clay, Freshwater Beds, Upper Marine.

We are now entering another new order of things, and a new æra of this world's history, where the transition from the chalk is as great, as that from the new-red-sandstone to the oolites. Though we have the same earthy ingredients; viz. clay, sand, marle, and lime; yet we have not the same consolidation. Throughout the primary and transition the prevailing characteristic is that of fusion and agglutination by heat: among the oolites and chalk, every thing has been effected by aqueous solution—the lime has cemented with its sparry or stalactitic depositions, and the sand has done the rest by petrifactions: so that almost every rock has a firm cement of lime and sand; and nearly every organic remain is a perfect calcareous spar or piece of silex—these substances having taken the place of the original component ingredient, and left only the impression. But the prevailing characteristic of the present series is a general want of induration. The clay is mostly soft and pliant, the sand unagglutinated, the marle unconcreted, and the limestone very imperfectly solidified. The shells in general have undergone no further change than the loss of their colouring matter and their gelatine, and might often be mistaken for recent specimens. Though the shells in the lower strata differ nearly as much from those of our present seas, as they do from those of the chalk; yet, in the upper beds, there is a regular gradation towards such as now exist. But here occurs a much greater variety of organic remains, especially of vegetable; nevertheless, their prevailing characteristic is still that of a warm climate.

The Plastic Clay formation is composed of sand and an indefinite number of subordinate clay and pebble beds, irregularly alternating, but altogether constituting one great series of nearly

contemporaneous depositions. In the Paris basin it is said to consist of two beds of clay separated by a bed of sand. The lower of these beds is properly the Plastic clay, from which the whole formation is named. It is unctuous to the touch, tenacious, and, when it does not contain much iron, is absolutely refractory in the fire;—hence its extensive use in all kinds of articles connected with pottery. Its colour also fits it for these various purposes:—being sometimes grey, yellow, grey mixed with red, almost a pure red, or very white. It is used as fire-clay, brick-clay, pipe-clay, potter's-clay, and porcelain-clay, according to its various degrees of purity. But it sometimes occurs as fuller's earth. The sand at Studland point, Dorsetshire, passes into limestone; but in all other places it is loose, and of an almost infinite variety of colour.

Its *minerals* are locally blended with the mass, and consist of pyrites, green earth, nodules of dark coloured limestone, selenite, fibrous gypsum, mica, and tubular ironstone. The *organic remains* are very irregularly dispersed, being sometimes in the sand only, at other times only in the clay, and in some places they are entirely wanting. They consist of many species of shells, with teeth of fish, and perhaps some bones of other animals. It contains imbedded layers of an imperfect kind of coal, that still bears decided marks of its vegetable origin, exhibiting even the branches and leaves of plants, among which has been observed the fruit of the palm tree.

Its surface is generally flat, especially on the N.E. of London; but on the S.W. of Hertford, it has considerable elevation; in some parts of Kent it swells into gentle eminences, but its highest point is about Dean-hill a few miles S.E of Salisbury. At Sundridge park near Bromley, the sea appears to have peaceably retired from it, leaving the strand almost an entire bed of loose gravel. In several places are beds of breccia or pudding-stone, consisting of small nodules of chalk flints cemented with silica. Its thickness at London is about 100 feet; at Woolwich, near 200; but where it is vertical in Alum-bay, Isle of Wight, it appears to be 1100 feet.

The London Clay in some places consists wholly of a bluish or blackish tough clay, but in others it contains calcareous matter, and assumes the character of marle; in the Isle of Wight it is mixed with a considerable quantity of green earth; at Bognor on the Sussex coast, are several detached masses of rock belonging to this formation—the lower part being limestone

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and the upper sandstone. The cliff near Harwich in Essex also contains masses of stratified limestone. The limestone on which Paris stands, called the *calcaire grossier*, and with which many of its buildings are erected, is, from the fossils it contains, supposed to belong to the same formation.

The most distinguishing characteristics of the London clay are its septaria and organic remains. The former consist of nearly horizontal layers of ovate, or flattish masses of argillaceous limestone; which generally seem as if they had been traversed in various directions by fissures that have been afterwards filled with calcareous spar, or sulphate of barytes. They occasionally appear to have been formed round fossil wood, and often contain shells still exhibiting the pearly lustre. They are burnt and ground for the manufacture of Parker's cement, used for stucco and building under water.

It contains martial pyrites in considerable abundance, and occasionally phosphate of lime, also selenite, and perhaps sulphate of magnesia; hence the impurity of its spring waters, which are supposed to be occasionally tinged with Epsom salts as well as muriate of soda. Though London stands upon this formation, yet most of the wells are in the superincumbent alluvium which affords an astonishing quantity of excellent water, and some of them are sunk entirely through this clay. When the *digger* has reached the Plastic clay, the fine soft water of that formation, generally rushes in so fast that it is over his head before he can escape:—but it rises to different heights at different places.

In excavating Highgate funnel or archway, which is wholly in this formation, fossil copal or resin was found; and amber is said to be occasionally discovered in the gravel pits about London. Amber is also found in a brown clay supposed to belong to this formation on the coast of Holderness, Yorkshire. In a like deposit, probably in the same stratum, it occurs in various parts of Europe, as France and Italy, but especially in Prussia where the greatest quantity is found, associated with a vast accumulation of vegetable remains. In several places of the Irish coast, in New England and Bermuda in America, amber frequently occurs.

No formation is more interesting as to organic remains. Of the amphibious class, it contains the crocodile and the turtle. There are various specimens of vertebral fish, and many species of the crab and lobster occur among the crustaceous. Few

genera of recent shells are to be met with, which have not some representative imbedded in this formation; among which are nautilites resembling those of the Indian seas. They seem to hold a middle character between present shells and those of the older formations;—chiefly differing from the latter in genera and from the former in species.

It frequently contains small portions, but sometimes even masses of wood, partially retaining the woody fibre; but it is oftener black with the appearance of having been charred. It also exhibits the perforations, and even contains the casts of a species of the *toredo navalis*, or borer, that infests the West Indian seas. But the most remarkable deposit of vegetable remains is in the Isle of Sheppy, where have been enumerated 700 species of fruit or ligneous seed vessels, very few of which agree with any now known. At Kew was found a species of the cocoa nut, with varieties belonging to the spice tribes. But wherever this formation is broken into, it always exhibits interesting specimens of fossils, and in so perfect a state as argues that they had not been drifted from a distance; a strong collateral proof of the existence of our great Atlantic continent, as also of another part of our theory, viz. that the earth had then a higher temperature than at present.

The surface of this formation is generally low and flat with gentle undulations, such as at Highgate and Hampstead. Its most elevated point is the summit of High-beach, Essex, 759 feet. Langdon-hill in the same county is 620. Danbury is not much less. Shooter's-hill, Kent, 446 feet. Richmond and St. Ann's-hill, Surrey, are of it. Its thickness, as found at different places, varies from 70 to 700 feet. Its strata are nearly horizontal, except in the Isle of Wight where it is nearly vertical, proving that the last subsidence which finally separated that island from England was posterior to this formation; it lines the bottom of the intervening strait called the Solent.

The American tract, between the Allegany mountains and the Atlantic, appears to be composed, principally, of this and the following formations. In lower Egypt, near the Pyramids, are traces of it; and shells from the foot of the Himala agree with those of the London clay. In Iceland is a hill of a similar kind of clay containing shells smaller than any now found in the neighbouring seas;—this is the only exception to the igneous formation of that island.

Fresh-water Formations of the Isle of Wight. We have had hitherto no decisive indications of fresh water strata. It is true we have seen a great many land productions, but all had been floated to their beds by the overwhelming flood of the ocean. We have now come to the contents of a fresh water lake, which seems to have been filled up with alluvium, though with occasional irruptions of the sea; and then its containing edges subsided and left a portion of the strata nearly in a horizontal state, so that we have in one instance a rounded hill made up, as it were, of a number of plates laid flat upon each other: the broadest, of course, occupying the lower part. This is Headon hill, which occupies a great portion of the north west part of the Isle of Wight. Its base is two immense beds of sand, which abut against the nearly vertical London clay. The lower bed is yellow, and above 100 feet thick, and seems nearly vertical; upon this is a bed of white sand of from 30 to 50 feet thick—much used in the manufacture of glass.

There are two distinct fresh water formations, separated from each other, by the upper marine formation. The *lower* one, which not only forms the lower part of Headon hill, but nearly all the northern part of the Isle of Wight, consists of a series of clay, sand, marle and siliceous limestone, mixed with more or less of a brownish coaly matter, and sometimes traversed by veins of calcareous spar. The quarries of Binstead were formerly of great celebrity, and furnished materials for many ancient structures, both in this island and the neighbouring counties, but it is now little used as a building stone. Its calcareous matter chiefly consists of fresh water shells, no marine exuviæ have been found in it. Three parts of the organic remains of this and the following formations belong to species now known. Its most elevated point is supposed to be Headon hill 90 feet, its thickness is 63 feet, and it dips gently towards the north. It is separated from the upper fresh water formation by the *upper marine*, which is here 36 feet thick, is a light greenish coloured marle, without any mineral contents; but with vast quantities of marine shells, some so perfect as hardly to be distinguished from recent ones. This is succeeded by six inches of sand, and then comes

The *Upper Fresh-water* formation, which consists of a yellowish white marle, with masses that contain a greater portion of lime; and it contains veins of some inches thick of pure

crystallized, and frequently radiated carbonate of lime; but in some places it contains excellent building stone. In Headon hill it is about 55 feet thick, and over it is 11 feet of yellow clay containing an unknown bivalve shell; and above that, another bed of yellow clay without shells. Next comes a bed of friable calcareous sandstone, also without shells, and above this another limy stratum, with a few fresh water shells; these beds are occasionally of a compact and porcelainous character, and are succeeded by a thick cap of alluvium, that raises the summit of Headon hill 400 feet above the level of the sea.

We have several indications of analogous fresh water formations in England, especially on the Hampshire coast, but apparently not of a decisive nature. In the Paris basin, which in most respects agrees with that of the Isle of Wight, some of the stone will admit of being polished as marble. The English varieties are destitute of gypsum, while the French contain numerous beds; and on the uppermost of which were found the bones of unknown birds and quadrupeds, together with a few fresh water shells. Fresh water formations occur in the S. W. of France surrounding Agen, and stretching to Pau at the foot of the Pyrenees; and near Aix in the north, and in other places near the Rhine. They are very frequent in the Subalpine district, and near the Appennines even forming ranges of low hills. They are not uncommon in Spain, Sicily, Dalmatia and Greece, and Malta is entirely composed of them. In the Norwegian friths are deposits, supposed fresh water, 100 feet above the sea.

The *Upper Marine formation*, consists of strata distinct from the London clay, but resting immediately upon it. It forms the substratum of Bagshot Heath and several adjoining tracts, also the low cliffs on the east coast of Suffolk, and occurs in the Isle of Wight between the fresh water formations as above mentioned.

Bagshot sand seems a generic term for all the tracts of sand found above the London clay. It consists of pure sand or sandstone; the former occasionally includes brickearth, and the latter imbedded chalk flints. The masses of rock called Sarsden stone, Grey Weathers, or Druid stones, of which are the principal masses of Stonehenge, and other detached masses overlying the chalk, belong to it. It covers Highgate, Hampstead and Hornsey hills, St. Ann's, and Shrub's hill near Chertsey. It chiefly crowns the higher parts of the London clay,

though not the most elevated, since its greatest height seems only to be about 463 feet. Its thickness is not known. It contains no minerals, and its few organic remains are very imperfect. It seems doubtful whether some of the rocky masses above enumerated do not belong to the Plastic clay. They are so hard as to require blasting:—Windsor Castle is built with them.

Suffolk Crag is a local name for this formation. At Walton Naze it constitutes about 30 feet of the upper part of the cliff; the lower part, (15 feet) being London clay. It chiefly consists of sand and gravel containing shells. At Harwich it contains masses of ferruginous sand somewhat cemented together, which is the only mineral substance that it exhibits. Most of its shells differ little from those of the neighbouring seas: some are inhabitants of distant seas, and others, though very few, are of extinct species. A few fragments of small bones of an unknown animal are peculiar to this bed. They are seldom more than half an inch in thickness, two in width, and twelve in length; and always have a flat, compressed form. They most frequently occur at Harwich. On this beach a large fossil tooth has been found, supposed of the mammoth. It seems to be of somewhat later formation than the Bagshot sand,—and its strata are nearly horizontal.

We have ground for the deduction that the Isle of Wight basin has partially shrunk since the deposition of the fresh water formations; but since the upper marine of the Hampshire coast is not identified with that of the Isle of Wight, we are not authorized to say that there has been any shrinking since the deposition of this formation; though it is certain that the surface of the ocean has subsided to a much lower level, being drained off perhaps by a subsidence in a distant quarter of the globe.

We have several instances on record of local subsidences which have taken place at no very distant æras. The Scilly Isles are proved, both by record and submarine works of human ingenuity, to have been half submerged since Strabo's time. According to tradition the sea has made great encroachments in Cardiganshire: the Bay once formed a Sixth Hundredth, there being now only Five. A submarine forest may be observed from the Isle of Dogs to Purfleet. In the year 245 the sea is said to have overflowed many thousands of acres on the coast of Lincolnshire, which have never been recovered. Along

this coast and part of that of Yorkshire, under the surface and considerably below high water mark, are remains of a forest of trees, which seem to have grown on a peat moor, that now extends under the sea. On the coast between Liverpool and Preston is a similar submarine forest; and a peat moor exists at a very low level in that country. Considerable changes with respect to the elevation of the surface, are also supposed to have taken place in the north-eastern parts of Cambridgeshire. In all these cases, the trees are standing upright in their natural position with the roots in the ground, and therefore have not been drifted from a distance. Besides these, have been local subsidences which occurred during storms, as at Horseford in Norfolk in the year 1745, when the soil sunk during a thunder storm. Also last March, 1824, in a province of Naples, the ground to the extent of about five acres sunk with a tremendous crash;—in the preceding night had been a dreadful storm in the Adriatic. For instances connected with this subject and the following chapter, see "THE HISTORICAL REMEMBRANCER."

The level of the sea seems to be generally rising in the Mediterranean and falling in the northern latitudes. From the commencement of the Christian æra to the middle ages, the sea rose, at the temple of Serapis near the Monte Nuovo, Italy, above 16 feet; and then subsided below its former level, and is now again rising. The sea is making regular annual encroachments on the eastern coasts of America; while in the South Sea between 44 and 46 deg. W. Long. and at about 62 deg. S. Lat. are islands or extensive perpendicular rocks, with the remains of whales and other sea monsters strewed over them; though these rocks have a volcanic appearance, but at considerable elevations on the sides of Ætna are marine shells. These shew that terrestrial subsidences are still going on; and that new rocks are forming, one instance will serve to prove. Near Aix, Provence, is a quarry of a deep grey limestone, which hardens on exposure to the air, and the strata of which are separated by beds of sand mixed with clay. At a depth of 50 feet and beneath the eleventh stratum, the bed of sand is covered with shells; and where it rests on the twelfth stratum were found, in 1786, broken columns and work tools, the wood of which was converted into agate, but the stone remained unaltered.

15. DILUVIUM.

THIS consists of a thick mantle of rocky fragments, and water worn pebbles, or sand and gravel, that in many places cover the whole of the other formations. It is different from the breccias and pudding-stone or conglomerates often imbedded in, and sometimes forming undulations, or hills upon the older rocks; and the distinction is of the most unequivocal kind, resting chiefly in its organic remains. These remains argue an æra long posterior to that of the latest of the above formations; and also of a much warmer climate than the present temperate zones, or the regions in which they are found. Among them the bones of the mammoth or fossil elephant are the most numerous, the others are of the hippopotamus, rhinoceros, mastodon, tapir, hyæna, tiger, and three species of deer, these belong to species now extinct, also to genera inhabiting warm climates. Along with them are found the bones of the bear, wolf, fox, weasel, horse, ox, hare, rabbit, water-rat, mouse, raven, pigeon, lark, and a species of duck and partridge.

The teeth, tusks, and bones of elephants of prodigious size have been found in the diluvium of Robin Hood's bay near Whitby, and at several other places southward on the Yorkshire coast, and in the interior of Norfolk, Suffolk, and Essex. The largest deposit is at Walton near Warwick, mixed with the horns of the elk and other diluvial animals. They are found in several places in the valley of the Thames, and have often been dug up beneath the streets of London; also on the southern coast of Dorsetshire, and Gloucestershire, and in the valleys connected with the Bristol Channel. They have been met with both in Scotland and Ireland. They are almost universally dispersed over the continent. In the valley of the Arno, near Florence, parts of the skeletons of at least a hundred hippopotami have been found mixed with remains of the rhinoceros, and elephant, together with those of the horse, ox, deer, hyæna, bear, tiger, wolf, mastodon, hog, tapir, and beaver. They are from animals of all ages, and one of the elephants could not have been above a week old. Between the mouths of the Lena and Indigerka, rivers of Siberia, are three islands of considerable extent, principally of diluvium, wherein these remains abound. The coast of Dalmatia is chiefly formed of them with the other diluvia. Remains of the crocodile and tortoise, as

well as fossil fish and plants of tropical origin are found dispersed over all the colder regions of the earth. In some parts of Siberia the fossil ivory forms a considerable article of commerce.

These, and other circumstances, prove that the countries where they are found, and that is wherever the science of geology has penetrated, have been overflowed by, or suddenly submerged beneath the ocean. The phenomena rather favour a quiet submersion than otherwise;--since the bones have no appearance of being water-worn, and their having been found in antediluvian caves, proves that the animals inhabited those regions; and consequently, that the bones were not floated by the sea from distant regions of the earth. The most remarkable of these caves is that of Kirkdale mentioned at page 462, and all the bones of the above list, except those of the tapir and mastodon, were found in it. The circumstances of this cave, examined by Professor Buckland, incontestably prove it to have been a hyæna's den, previously to the flood in question.

Now there are two or three circumstances which seem to identify this great revolution of the earth's surface with our theory: viz. the universality of the organic remains, and the evident change in the earth's temperature. "Even Iceland contributes its share, and has furnished the jaw, the cranium, and a tooth of the fossil elephant. In the Mediterranean, they are found not only in the greater islands, such as Sicily and Cyprus, but in the smaller, such as Santorini and even Cerigo; in which last an elephant could hardly find food for a single week. These places, therefore, when they were inhabited by such large animals as the elephant, or the rhinoceros, must have made part of a great wooded continent, in which Iceland and Cerigo were included." The fresh water formations of Malta, as well as those of the Isle of Wight and Paris basins; and the bones on the coast of Dalmatia and in the rock of Gibraltar are all farther proofs of a great continent. Now suppose this diruption of the great continent was the result of a general concentration of the earth's mass, however caused, whether by the approach of a comet or by any other means, it would occasion a great revolution with respect to changing the bed of the ocean;—for that part of the land which had the least of the secondary formations upon it, or had obtained the least matter by former subsidences, would fall the lowest, and consequently would

drain the water from other parts. But while this concentration was going on, there would be a great emission of caloric, which perhaps might raise the temperature of the ocean to near the boiling point; but the earth thus losing so much heat, would for ever present a less temperature at the surface; hence the organic remains indicate a warmer climate than we now experience. The subsidence of the continents and the temporary increase of the temperature may perhaps have been instrumental in effecting this Universal Deluge; but after all, our theory is not required to explain by natural means, what we believe to have been effected by a *peculiar interference* of DIVINE POWER.

CHAP. XVI.

Meteorology.

1. Atmospheric Electricity. 2. The Aurora Borealis. 3. Earthquakes. 4. Hurricanes. 5. Whirlwinds, Water Spouts, and Pillars of Sand. 6. Lightning. 7. Meteors or Fire Balls and Aerolites. 8. The Precipitation of Vapour or Rain. 9. Hail. 10. Snow. 11. Wind 12. Atmospheric Temperature.

1. ATMOSPHERIC ELECTRICITY.

Evaporation always excites electricity, as when a burning coal is thrown into a vessel of water,—the vapour is positive and the remaining water and vessel are negative. Under the torrid zone, where the falls of rain are great, and the evaporation is according to the heat, the atmosphere is highly charged positive, and the earth as highly negative. Indeed, all the earth's surface is more or less negative, either by immediate evaporation, or by induction, that is, by the positive fluid of the warmer regions passing along the atmosphere towards the colder regions, as from the torrid zone to the frigid zones. And this terrestrial charge is always strongest in elevated situations, as on the top of St Paul's, and on the summits of hills and mountains; and its intensity varies with the weather. Hence on the Alps and sometimes on less elevated hills, when the weather will be fine, the fleecy clouds, in the morning, are seen gliding slowly and peaceably along the ridges; but immediately preceding rain or stormy weather (being disturbed by the electricity then abounding in the mountain,) their motion is very irregular; and they are frequently seen, especially before hail storms, dancing or rebounding with great rapidity.

The part of the atmosphere immediately upon the earth's surface is sometimes negative, and sometimes positive; but the upper regions are supposed to be always positive. Saussure found the air positive, though weakly so, upon Mont Blanc. When the French mathematicians, that went to measure an arc of the meridian under the equator, were upon a high ridge of the Andes, they frequently saw highly charged positive clouds descend from more elevated regions. These clouds often enveloped them, but sometimes they descended to a stratum of clouds about half way down the mountain; and when these two sets of clouds came in contact, they produced thunder and lightning, with all the terrific phenomena of the most violent storms.

Instruments called *aerial electrometers*, are used to ascertain the quantity and quality of the atmospheric electricity. They consist of a metallic rod, somewhat in the shape of a fishing-rod elevated perpendicularly in the air. They are insulated, but communicate with a proper electro-apparatus at the bottom, where the observations are made. On some occasions, when the wind is favourable, a common school-boy's kite is used:— a wire thread being twisted into the string, which answers the same purpose as the metallic rod. No great danger attends the use of either of them, unless when thunder clouds prevail, on which occasions fatal accidents have happened with the use of both.

From these, it has been found, that in cold, dry, and serene or frosty weather, the atmospheric electricity, at least near the earth, is negative. When dark or wet weather clears up, it is negative. But in warm, fresh weather, whether dry or moist, it is positive: a low thick fog rising into dry air is generally highly positive. In the morning, when the hygrometer indicates dryness equal to the preceding day, positive electricity obtains before sun rise; it increases with the ascending sun, especially if the dryness increases, and through the middle of the day is proportionate to the heat. It diminishes towards evening, but for the most part, when there is a clear sky, and little wind, a considerable electricity rises at dew-fall; however, through the night it is mostly negative. Some clouds are positive, and some are negative: and in stormy weather when the clouds are seen rolling over each other, the electrometer sometimes indicates a change of the fluids so rapidly, that the observer hardly has sufficient time to note them down.

The above excitation of the electric fluids is the result of the solar heat. But as we have already shewn that the earth contains a heated nucleus, and that its heat, occasioned by subsidences, often approaches nearer its surface in some places, as in volcanic regions or on primitive mountains, than in others; so we have here electric charges of much greater intensity:—hence, in some cases, it is difficult to determine whether an earthquake and its accompanying electro-phenomena were caused by a subsidence; or, that electric charges merely collected from the excitation of the solar heat, occasioned the earthquake, and those partial subsidences or fissures in the strata which they often produce. However this may be, we consider these charges and discharges of the electric fluids as the cause of the various phenomena treated of in this chapter.

2. AURORA BOREALIS.

The *aurora borealis, streamers, or northern lights,* are those beautiful and sublime, though sometimes terrific lights that are occasionally seen in different parts of the world, but especially in the north west, or in that part of the earth, wherein we suppose the magnetic pole to be situated, and with the position of which they seem to be somehow or other connected. They are very frequently seen in Scotland and in the Shetland Isles, where they are called the *Merry Dancers.* They are the constant attendants of clear evenings, commonly appearing at twilight near the horizon of a dun colour approaching to yellow, and frequently seem motionless for some hours. On some occasions they assume the appearance of vast columns, on one side of the deepest yellow, and on the other, declining away till it is indistinguishable from the sky. They partly appear as if curtains of a russet colour were tightly stretched perpendicularly, but horizontally so loose as to be in folds; and behind these are the yellow brilliant lights, moving along the whole hemisphere more rapidly than the eye can follow. Sometimes they form beautiful prismatic columns, vertically arranged; at other times, they form arches, circles, ellipses or coronas; and they often have the appearance of flaming spear points darting upwards, hence they have been compared to fiery warriors rushing to battle.

But they only appear thus when viewed at a distance; in the northern regions, where they are vertical, they are seen to per-

fection. "They begin," says an author who witnessed them in Lapland and Siberia, "with single bright pillars rising in the north and almost at the same time in the north east, which gradually increasing comprehend a large space of the heavens; rush about from place to place with incredible velocity, and finally cover the whole sky up to the vertex. The streams are then seen meeting together in the zenith, and producing an appearance as if a vast tent was expanded in the heavens glittering with gold, rubies, and sapphire. A more beautiful picture cannot be painted. But whoever should see such a *northern light* for the first time, could not behold it without terror. For however fine the illumination may be, it is attended with such a hissing, cracking, and rushing noise throughout the air as if the largest fireworks were playing off. The hunters are often overtaken in their course by these northern lights, or as they call them *Raging Host*. Their dogs then are so much frightened, that they will not move, but lie obstinately on the ground till the noise is passed."

The altitude of the northern lights is variously stated. Some have affirmed it to be between 8 and 900 miles. Bergman, from 30 observations, deduced a mean of 469 miles; and Euler makes it thousands, so that it seems they extend to the very limits of the atmosphere. And according to the account of Capt. Franklin's expedition in the Artic regions of North America, they were generally, as low as within 6 or 7 miles of the earth's surface; and on one occasion, they were within two or three feet of the ground. Their proper region seems to be that which we have assigned to the cirro-modification of clouds. This region is considered as that of fire-balls, and the aurora has sometimes been known to unite and form a number of them.

The mariner's compass is greatly affected by the aurora-borealis, so that the needle is in continual agitation, and plays backwards and forwards, through an arc of 3, 4, or 5 degrees. According to Capt. Franklin, who, when he made the observation was near the place which is assigned to the north magnetic pole, it is the most common between the 64th parallel of north latitude and the arctic circle. From this it is evident, that the aurora has some connection with magnetism: probably it may be as follows. Wherever a charge of the one electric fluid is present, a corresponding charge of the other is sure to be in the nearest conducting surface. Now as we have shewn that the excitation of electricity in the torrid zone is much greater than

in the other zones, and have also supposed that the positive fluid passes along the upper regions of the atmosphere from the torrid to the frigid zones; consequently a corresponding charge of the negative fluid will also pass along the earth or lowest region of the air,—may we not, therefore, consider such two charges as bearing some resemblance to a magnetic molecule? and if so, it may perhaps be hereafter shewn, from some of the many experiments now going forward in Electro-magnetism, that such charges, especially if the positive be in a small cloud, are under some magnetic influence of the earth; and that their transmission northwards is a mere tendency to arrange themselves at the magnetic pole, where, by a concentration as it were at a nucleus, the fluids are discharged and produce the aurora.

That these lights are occasioned by charges of the electric fluids, escaping through the air in irregular streams and not shocks such as produce earthquakes or thunder and lightning, is evident from their preceding earthquakes, and their being exhibited in the atmosphere directly over where the earthquake is about to take place. An instance will be mentioned in the following section. And a peculiar one of this nature is related by Mr. Fisher in his account of Capt. Parry's first northern expedition. The latitude of the observer was somewhere about 74 N. and 110 W. Long. "Nov. 17. between 3 and 4 o'clock P.M. a remarkable cloud was observed S.W. centre S.W. by S. It diverged from a centre at the horizon, in straight lines or columns which extended to a great distance over the surface of the sky; the lowest edge on each side was very straight and well defined, and formed an angle of about 40 degrees with the horizon. Directly over its centre, instead of straight lines, it had more the appearance of an immense volume of smoke than any thing else. The whole was compared by our gunner to a powder magazine in a state of explosion, which, those who had had an opportunity of seeing such a sight, thought a very apt comparison. For the reflected rays of the sun, which illuminated that part of the sky beyond the cloud, gave it very much the appearance of an immense explosion. It is possible (says he) that this remarkable cloud had some connection with the aurora borealis; for after it had vanished, which took place about 6 o'clock, that phenomenon was seen in the same part of the heavens which the cloud had occupied. It made its appearance indeed before the cloud disappeared entirely, but not be-

fore it had lost its radiated form, and dispersed so much that nothing could be seen about it."

This cloud with other nearly similar instances on record, is much in favour of our hypothesis, viz. that the aurora is caused by the negative fluid bursting from the earth, charging the lower regions of the air, and joining the positive in the upper. The earth on account of its density, contains its charge in a much less space than that in which the opposite charge is contained in the air. And as cold, dry, and dense air is so bad a conductor that electricity can only force its way through it in shocks or pulsations; so, being mustered to a point in the earth's surface, it darts up through the lower regions of the air, exhibiting the appearance of fiery spear points. But as the corresponding definite proportion of the positive fluid is dispersed perhaps over an area of thousands of miles in the ethereal regions, while the negative occasionally escapes as it were by a mere orifice, and the extreme tenuity of the air (though in this case a conductor) prevents the positive from forming a shock, therefore, it must slowly combine with the negative, and the streamers will diverge from this central orifice at the earth's surface towards the extensively charged surface in the ethereal regions. What seemed to be a volume of smoke was probably nothing more than the vapour contained in the air collected and condensed into a cloud, with the peculiar form and motion of a water spout, which being viewed at a distance, may be easily conceived to have the appearance which he describes. Moist air is a conductor of electricity, consequently, while this vapour of the cloud was in contact with the earth, it perhaps conducted the positive electric fluid to the earth—but as soon as it was dispersed the aurora or aerial combination commenced. The arched and elliptical appearance which the aurora often assumes, is the mere result of our viewing it in profile;—the above might be in reality circular in the regions of the air, when a distant profile view would cause it to appear elliptical, while a stream across the heavens, as is the case with streams of vapour or clouds, would give it an arched-like appearance. (See sec. 6.)

The autumn is the season in which these lights are the most frequently seen, when the earth is covered with snow; but more especially when an intense frost is succeeded by a thaw. Snow is a much worse conductor than either air or water, and

therefore by the snow the electric fluid is pent up in the earth. That they should be the most frequent in autumn has nothing singular in it, since hurricanes generally happen where the sun has receded about a month, from the zenith of that place. And as earthquakes and thunder and lightning are the most severe at the sea shore, or on the summits of mountains, may we not suppose that Mr. Fisher's cloud had its centre of divergence either at some sea shore, or on the summit of some mountain, while the land or plain was fast sealed up with snow? As to the aurora appearing after a thaw, it is the junction of the two fluids that causes the thaw; and then the vapour increases the conducting power of the air, so that the negative fluid charges the lower regions of the atmosphere, and darts up towards the positive in the ethereal regions, producing what we call the *streamers*. Dry, cold, and dense air, says Walker, is a non-conductor of electricity; while moist, or rarefied air, as by an air-pump, is a conductor.

The *Aurora Australis*, or Southern Lights have been seen, but the observations are too few for us to draw any inference, whether they are connected with the south magnetic pole, or whether they were all, as some of them undoubtedly were, mere volcanic discharges connected with earthquakes and hurricanes.

An artificial representation of the aurora borealis is founded on the extreme tenuity of air. When an exhausted glass tube is positively electrified, flashes of light vibrate in it exactly in the manner of the streamers. If the tube is quite exhausted, the light is a bright yellow or white; but if a little air is admitted, it becomes a purple. When the tube is quite dry, it will continue at intervals to emit faint flashes for twenty-four hours. Hence it is, that when we view the northern-lights at a distance, we see only that part in thin air, of a bright white or yellow colour; while those who have them vertical, and consequently view the part in dense air, describe them as occasionally assuming the ruby and sapphire hue.

3. EARTHQUAKES.

Though all the phenomena of this chapter are nearly related to each other, yet earthquakes have this peculiarity, viz. the union of the two electric fluids, which produces the concussion

denominated *Earthquake*, takes place in the earth, while in all other instances, it is in the atmosphere.

As earthquakes are the most violent paroxysms of nature, the prognostics are in proportion, and are therefore the most appalling. They generally, though not always immediately, succeed a long drought with very cold weather. Immediately before the calamity, the air exhibits all the electric phenomena, such as falling stars, and the aurora. The sun is obscured, while no cloud is visible; the moon and stars are dim, with burs around them; whirlwinds and strangely sudden gusts are frequent, though in general an awful stillness of the air prevails. Some people are most acutely sensible of the approach of the shock, being seized with giddiness, faintings, shortness of breath, and all the symptoms which accompany a high charge from an electric battery. In others, it produces acute rheumatic pains, and a long train of nervous disorders; and with the shock, some are struck dead. Animals are still more sensible of its approach than man; and are almost terrified to death. Before the earthquake of Messena, orders were issued for putting all the dogs to death, so dismal were their howlings. As the discharge is principally from wells, ponds, and rivers, so geese seem the most sensible of all; and should they be in the water during the shock, they immediately fly from it, nor can they by any means be forced back again.

With the shock, the water is often precipitated from the bottom of the wells, or from the turbid fountains are emitted dreadful stenches. The sea lifts its waves with awful roarings, sometimes in mountainous billows, and at other times in cone-like water spouts or boilings up. The earth is often seen rising up in conical hillocks, or dimples are made in it like hollow cones reversed; and wherever it opens, it emits flames and sulphuretted blasts. In the mean time noises are heard under-ground, sometimes like the rattling of chariots, which occasionally increase till they resemble the firing of cannon. In the air the noise is like the rushing of mighty winds, with peals of thunder, and the zenith shortly assumes a dullish colour, having the appearance of the inside of a red hot oven.

At the commencement of the earthquake, which sunk Port Royal, Jamaica, in the year 1692, the streets rose up in undulations like the waves of the sea; at the same time exhibiting the most frightful chasms, which swallowed up houses and their

inhabitants, and in the space of about two minutes engulphed them forty fathoms deep. Although the sinking of Port Royal gave name to the earthquake, yet more houses were left standing in it than in all the rest of the island. The greatest concussions were among the mountains, so that the people imagined the cause lay among them. Shocks continued for two months, sometimes two or three a day, with openings of the earth that emitted vast quantities of sulphurous acid gas. And, though the people who had escaped the first calamity resided principally in boats on the sea during that period; yet, so great was the mortality caused by the vitiated air, and electrified surface of the earth, that three thousand people were swept away by sickness. The great earthquake of Sicily happened in the following year, and is accounted one of the most terrible known. By it, fifty-four cities, including Catania, with an incredible number of villages, were either overthrown or damaged. In Catania, out of 18,900 people, only 900 remained.

In 1749 there was an earthquake in London extending ever a circuit of 30 miles diameter, but no eruption of any kind. This was succeeded by a more dreadful one in the following year. Before this latter, the weather had been for five or six months uncommonly warm; the wind S. and S.W., without rain, but vegetation was very rapid. Fire balls were seen to issue from the earth, and meteors to play about in the air; the aurora had been very common, and had been twice seen in unusual colours even to the south of London, so that the Italians foretold an earthquake. At length a black cloud coming over London, and beginning there to be precipitated in rain, the moist air formed the electric circuit, and the shock ensued.

The above earthquake extended to Portugal, where three or four shocks were perceived the same day; and the four succeeding years were one continued drought, so that the most profuse springs in that country were dried up. N. and N.E. winds generally prevailed, attended with slight tremours of the earth. The summer of 1755 proved very wet and cold; in the forty days immediately preceding the following awful event, "The Earthquake of Lisbon," the air was principally free from clouds, but not very clear. The day before the calamity, the sun was obscured by a remarkable gloomines. Early next morning, Nov. 1st, a fog arose, but was soon dissipated by the sun. The sea was calm, no wind, and the weather a good deal warmer than usual. At Lisbon, 35 minutes past nine o'clock

A.M. without any warning, except a noise similar to the artificial thunder in the theatres, a perpendicular shock was felt, which was, with little or no sensible intermission, succeeded by motions from east to west. They continued about six minutes, and buried nearly all the inhabitants of Lisbon beneath the ruins of their houses. Another shock was felt about noon, which completed the catastrophe.

Though Lisbon suffered the most and gave name to the earthquake, yet the concussion seems to have been the most tremendous in the mountains of Portugal, whence issued flames. Nor was its effects confined to that country, for they extended over a circuit of the earth's surface including an area of not less than four million square miles. They reached, eastward, as far as Switzerland, Italy, Tunis, and Tripoli, in Africa; at Arzilla, a town in Fez, a ship was lifted up and broken on the sands, and a boat was cast from the sea to the distance of two musket shots inland. All the north-west coast of Africa suffered. There were no means of tracing this earthquake further south than the Madeira isles, where, at Funchal, simultaneously with the first shock at Lisbon, the sea rose with the half ebb tide 15 feet above high water mark. Similar risings in other places were observed, and at Lisbon a wave rose as high as 50 feet. In different parts of the Atlantic, where ships happened to be, they seemed as if struck upon a rock; and in several places the bottom of the sea rose up like an island, emitted flames, and then sunk. It extended as far westward as Barbadoes and Antigua; and northward to England, Ireland, Scotland, Norway, Sweden, Germany, and Holland; and thence again to the mountains in Switzerland. In England it principally ran along the western parts of the island; but in all places seemed to keep itself chiefly to the hills, sea-shores and waters. And although a shock and tremour were felt all over both Great Britain and Ireland, the chief effect was produced in the wells and ponds, from some of which the water was thrown out in one sheet; and in others, it became turbid and possessed of a sulphurous stench.

The earthquake that occurred in Italy, 1783, continued from the 5th of February to the first of March: all which time the sky appeared in flames, so that the people imagined the day of Judgment was come. The earth had almost continual tremours and whirling-like motions. Before a shock the clouds were still, then came a shower of rain, and immediately after, the

shock ensued. The year preceding this earthquake had been remarkable for the cold that prevailed all over Europe.

Earthquakes seem principally confined to near the earth's surface, though that of 1755 was more severely felt in the mines of Derbyshire at 132 yards below the surface, than upon it; and at Lisbon, a quay, upon which stood a multitude of people, sunk to an unfathomable depth, nor was ever one of their dead bodies found. However their seat seems to be in the earth's external shell. And they are likewise chiefly confined to particular regions, so that where they have once been, there they the most frequently occur. Volcanic regions are identical with those of earthquakes, and during an eruption continual tremours of the earth are always felt; but indeed all the volcanoes of the neighbourhood always pour forth a most tremendous eruption along with each shock. Near the foot of the highest Andes earthquakes are of almost daily occurrence, and for that reason the houses are in some districts built entirely of wicker.

That earthquakes are the shocks occasioned by vast discharges of the electric fluids, cannot be doubted; and it is equally evident that one charge, the negative, is contained in the earth, and the other, or positive, in the atmosphere;—but it is not so evident whence arise these immediate charges. Earthquakes are generally preceded, though not always immediately, by a long season of cold weather. Atmospheric warmth, or what we call fine, warm, fresh breezes, are occasioned by the positive fluid of the atmosphere coming in contact with the earth's surface, perhaps attracted by the negative fluid therein contained, which is thus liberated and combined with the positive. But in cold weather, when piercing cold winds prevail, the positive fluid never descends below the more elevated regions of the atmosphere. By a long continuance of such weather, may those immense charges be accumulated, which finally, by their forcing themselves through the non-conducting medium of the lower regions of the atmosphere, produce the earthquake. On these occasions, the combinations of the two electric fluids take place both in the earth's shell and in the atmosphere, the former producing the shock called the earthquake, and the latter the accompanying aerial phenomena. Yet this morbid state of the earth's surface and the lower regions of the atmosphere seem to be somewhat out of the regular course of nature, or to proceed from some hidden cause. The earthquake of 1755 was plainly

connected with the area of those subsidences, which gave birth to the Atlantic Ocean and depressed the western border of the great geological basin of Western Europe so much below its eastern border, or the Alpine level, mentioned in various parts of the preceding chapter. That there was any actual subsidence in this area during this earthquake, is not evident from recorded facts, though the sea certainly changed its bed a little in some places. But the constant occurrence of earthquakes in volcanic regions and during eruptions, is a strong proof, that they sometimes proceed from charges resulting from the earth's internal heat: at the same time, it should be observed, that a very small movement in any subsided area, as in the bed of the Atlantic ocean, would be sufficient to resuscitate the internal heat of the earth and produce the above excitations of the electric fluids. And if these almost imperceptibly small shrinkings of the terrestrial mass, produce such awful electric phenomena, what would those be which were produced by those subsidences that took place when our primary and transition mountains received their birth amidst this strife of elements!

4. HURRICANES.

EARTHQUAKES and hurricanes are so nearly allied that the latter seldom occur without some shocks of the former; and earthquakes, as that of Sicily, 1783, are often accompanied by an impetuous, roaring wind. But harricanes are almost peculiar to the torrid zone: and depend more particularly on the air being in such a state, by the quantity of vapour which it contains, as to hold an immense charge of the positive fluid; so that the combination, on account of this vapour making the air a conductor, is principally in the atmosphere; while in earthquakes, there being little vapour in the air on account of the cold weather which generally precedes them, the combination is chiefly in the earth's shell. Hurricanes, it seems, are almost entirely confined to islands and the sea-coasts, the moist shore, probably, making the earth a conductor so as to form the circuit between the positive in the air and the negative in the earth. They are also very frequent on the summits of primitive and volcanic mountains, but such places not being inhabited, they are little attended to. The prognostics of earthquakes and hurricanes are nearly the same; the principal difference seems to be in the length of time that those prognostics continue: earth-

quakes are sometimes years in brooding, while a month or so it seems is sufficient to mature a hurricane.

Hurricanes principally occur in the West India Islands, but are not unfrequent on all coasts within the tropics. The native Carribees of St. Domingo, and St. Vincent, are said to be skilful in foretelling them. Their rule, is, that they take place either on the day of the full or change, or at the quarters of the moon; and the prognostics are a number of phenomena in the preceding quarters; viz. a troubled sky without clouds, a universal calm, sun red, the moon and stars appear larger than usual, and with burs around them. Nearer the principal discharge, noises are heard in hollows and cavities of the earth. The sea has a stronger smell than usual, and in the midst of a profound calm, boils up in places, or immediately rises into mountains, on which occasions it becomes remarkably clear. A westerly wind blows with irregular intermissions, sometimes violently for the space of an hour or two, when all is quiet again.

When the discharge takes place, the thunder and lightning are terrific. Tremours of the earth are felt, and the wind rushes in from all quarters, with the noise of cannon, levelling and tearing up every thing before it. (See Wind, Sec. 11). The sea lifts its waves, being charged with the negative fluid, to an unusual height; which, being further propelled by the wind, has sometimes swept over whole islands. Fields of sugar-canes are torn up by the roots and scattered through the air. Houses, with their inhabitants, are swept away into the sea; or, they are, with the fragments of broken and uprooted trees, buried in one promiscuous heap of rubbish, or floated away in some rapid river, which has just had birth from the rain that is all the while pouring down in floods.

Tornadoes are hurricanes on a smaller scale, and are often experienced by mariners near the tropics. The prognostics of the air, are to a certain degree the same. On some occasions the electric fluids may be seen collecting to a point in a cloud, on the highest pinnacle of a cliff, or on the mast head. This appearance is known among seamen by the name of the *ox-eye;* and is a sure prognostic of a most violent storm. When the discharge takes place, it is from this point. If it is in the air, a most dreadful clap of thunder is heard; if on the cliff, it is rent with the tremour of an earthquake; and if, as is frequently the case, in common thunder storms, the discharge is from the

mast, it is shattered to pieces, and the ship is set on fire. On those occasions the wind rushes in from all points of the compass; and often with a whirling motion, so that the ship is suddenly whirled round. Off the coast of Guinea they have sometimes three or four such storms in a day, preceded by clear, serene, and calm air. A more dreadful kind occasionally occur in the East Indies, as off Madras or Pulicat, where a branch of the Ballagat mountains extends towards the sea. They are also frequent on the shores and among the islands in this part of the world; but it must be observed that most of these islands are the summits of primitive mountains, thus depressed to the sea level; and some of them are volcanic.

5. WHIRLWINDS, WATERSPOUTS, AND PILLARS OF SAND.

WHIRLWINDS are bodies of the positive fluid reaching from a cloud to the earth, and in this columnar manner, moving along sometimes with great rapidity; and, electrifying the air with which they come in contact, cause it to ascend with the utmost velocity, so that the surrounding air rushes in from all sides and occasions the whirling motion. When the positive fluid thus stoops down, as it were, from the clouds, it seams to do it with a point; or, when it touches the earth, it resembles a cone or speaking trumpet, standing on its apex and having its base among the clouds. And as it is the nature of the electric energies, when sufficiently condensed, to have a rotatory motion on the central point of attraction, so we may suppose that the body of electric fluid in question, may have a whirling motion, which causes the gyration of the substances it takes up.

Whirlwinds generally occur in calm, droughty weather. They are not often injurious in this part of the world, but near the tropics and in the torrid zone they are frequently very destructive. A kind of whirlwind, distinguished by the name of Typho, from its following the course of rivers, often does great damage in the warmer climates. One instance, which occured June 1st. 1761, near Charlestown, South Carolina, may serve to shew their nature. It was first observed by land, 50 miles W. by S. of Charlestown. It destroyed several houses as it passed along; tore up trees and shrubs, so as to make avenues through the woods that opposed its passage; and took up their shattered branches in its column. It directed its course to Ashley river, down which it descended with great

velocity, but tumultuous irregularity of motion, having the appearance of a column of smoke or vapour. It ploughed the river to the bottom and laid its channel bare, making a noise all the way like thunder. At this place the diameter of its base was calculated at 600 yards, while that of some of our smaller whirlwinds is not more than an inch. It was met by another of the same kind but of less force, that came down Cooper river, and at the junction of the rivers the typhons united, when the air became more violently disturbed and to a much greater circumference. The clouds, which were hastening from all quarters to join it, seemed as they came near to partake of the same whirling motion. After this it came upon the shipping in the river, destroying some and injuring others. It passed about six miles in three minutes, and did considerable damage.

Whirlwinds on land are *waterspouts* at sea. These are generally the productions of warm climates, but are not unfrequent on our coasts. They generally have the appearance of a speaking trumpet hanging from the clouds: the upper part is white, and the lower black or like a dense cloud. The spout generally hangs down perpendicularly, but is sometimes inclined, and at other times curvated. It always has the whirling motion, and not unfrequently the spiral form. Beneath the point, the water of the sea seems to rise up with a direct cone to meet the other, and in such a manner, that it is frequently not known which was the first formed, though the boiling up of the water generally has the priority. The water at the surface of the sea forming the base of this cone is sometimes agitated over a space of more than 100 yards diameter, whirling to the centre where it ascends from the top of the cone like a *Jet d'eau* terminating in a dense vapour. At the same time the lower point of the upper spout seems hollow, into which the vapour enters and ascends with a whirling motion, apparently forming a tube inside as it ascends.

However waterspouts differ very much in form as well as in size and duration. Sometimes they continue for an hour, at other times they disappear and form anew several times within a quarter of an hour; and very often a number of them appear at once. They always terminate in a dense, turbid but generally whitish cloud, and are carried off to be dispersed over the land in rain. But they sometimes burst, that is, their contents are poured down in a mass of water, and sometimes they precipitate a quantity of hail. Mariners have often burst or dispersed them

by making a noise, by firing at them with ball, or even, as it is said, by pointing a sword or metallic rod at them, so as to disturb the electrified medium. At the moment of bursting they are always enveloped in a flash of lightning; so that, should they come in contact with a ship, it would almost inevitably perish as well by the electric shock as by the fall of water.

Water-spouts generally appear in the months most subject to thunder and lightning; and are, for the most part, preceded, accompanied, or followed by rain and hail. They are always attended by a noise resembling the clatter of a mill, which on some occasions is as loud as thunder; they are accompanied also by lightning, which often plays around them with great velocity. They have been known to pass from sea to land, when they exhibited all the phenomena of whirlwinds. Sometimes a commotion among the clouds is first observed, which assuming the whirling motion, let fall the pointed and often screw-like tube; and in this manner have they frequently been formed inland.

In the year 1718 a spout burst on Emott Moor, Lancashire, covering a space of ground 22 yards in width, tearing up the earth to the rock which was seven feet below the surface. But it did not precipitate at once, for the ground was ploughed up in the above manner forming a trench or gulf half a mile in length:—the earthy materials being piled up in prodigious heaps on each side. The adjoining country was immediately inundated. Switzerland and all other mountainous regions are subject to a kind of hurricane. Attended by thunder and lightning, tremours of the earth, and waterspouts, and that at all seasons of the year. The whirlwinds on such occasions sometimes raise the water from the lakes in the form of a pillar, reaching up to the clouds; and let it fall in a body upon the land frequently doing much mischief.

In Germany, on the 20th of July, 1751, at three o'clock P. M. a great quantity of dust was observed rising from the ground and covering a field and part of a town in which the observer was. There was no wind, and the dust moved gently towards the east, where was a great black cloud, which passing the zenith charged the electrometer *positive*. Advancing westward the dust followed it, rising higher and forming a thicker pillar in the shape of a sugar-loaf, till it came in contact with the cloud. At some distance there came in the same path another great cloud. It moved faster than the preceding one, and was attended with a long train of smaller ones. These clouds

charged the apparatus negatively; and when they came near the positive cloud, the whole were enveloped in a flash of lightning. Upon this the clouds dissolved in rain, and the air was soon clear of all the dust. Whirlwinds have occasionally presented the appearance of a column of fire, as was the case with one at Holkam, Norfolk, 1741.

An artificial waterspout may be made by suspending a drop of water by a wire over a vessel of water, and charging the wire positive, when the drop assumes the waterspout form; and the water in the vessel, being in the electric circuit, is negatively charged, so that it rises up to meet the spiral drop.

But it seems that the same electric charges which cause waterspouts at sea and whirlwinds on land, occasion *Pillars of Sand* and the poisonous simoom in the burning deserts of Africa. Bruce gives a lively description of these awful phenomena. "We saw," says he, "a number of prodigious pillars of sand at different distances, at times moving with great celerity, at others, stalking with majestic slowness; at intervals we thought they were coming in a very few minutes to overwhelm us, and small quantities of sand did more than once actually reach us. Again they would retreat so as to be almost out of sight, their tops reaching to the very clouds. There the tops often separated from the bodies, and these once disjointed dispersed and did not appear again. Sometimes they were broken near the middle as if struck by a large cannon shot. About noon they began to advance with considerable swiftness upon us, the wind being very strong at north. Eleven of them ranged themselves alongside of us at about the distance of three miles. The greatest diameter of the largest appeared to me at that distance as if it would measure about ten feet. They retired from us with a wind at south-east. But before four o'clock in the afternoon, these phantoms of the plain, had all of them fallen to the ground and disappeared.——Two days after this the same appearance of moving pillars of sand presented themselves, only they seemed to be more in number and less in size. They came several times in a direction close upon us, that is, I believe within less than two miles. They rose immediately after sunrise like a thick wood, and almost darkened the sun: his rays shining through them for near an hour gave them the appearance of fire. Our people now became desperate; the Greeks shrieked out and said it was the day of Judgment. Ismael pronounced it to be hell, and the Tucorories (the name of the people

who had joined us) that the world was on fire. I asked Idris if he had ever before seen such a sight. He said he had often seen them as terrible, though never worse; but what he feared most was that extreme redness in the air, which was a sure presage of the coming of the simoom."

6. LIGHTNING.

LIGHT and Caloric are always produced by the union of the two electricities; but though a great deal is extricated during earthquakes and hurricanes, the mind is too much occupied with the more tremendous concussions to dwell much upon the lightning, and in common rains the combining fluids are so much dilated as not even to produce light visible by night; so that the discharges more peculiarly distinguished by the term lightning in our climate, are those which take place among the clouds, when the concussion of the air causes the sound called *thunder*. Thunder and lightning seldom or never occur in the frigid zones, while on the contrary in the torrid zone they are of almost daily occurrence, and are awfully destructive. As the air is frequently charged to the earth's surface the lightning is often seen to run along the ground. And indeed in the temperate zones it is sometimes so tremendous that fire-balls play about or vibrate in the air.

We have already shown how the upper regions of the air become positively charged, and the earth negatively: and either by means of nightly dews or rains in cold climates, the lower regions of air become negatively charged: hence originate negative clouds. In cold regions, as in the frigid zones, these clouds are never more dense than the thin stratus; hence their rains are never heavier than a haze, and instead of the atmosphere being relieved of its electric fluids, as in the temperate zones by thunder and lightning and heavy rains, or as in the torrid zone by still more heavy rains and hurricanes, the charges are widely dispersed through the cold non-conducting air and produce the aurora borealis. But in the temperate zones where the temperature of the air is greater, especially in summer, more dense clouds are formed; and the air having a conducting power in proportion to its heat, the clouds are capable of containing a high charge, so that two, oppositely electrified, may frequently be seen to approach each other by their mutual attraction.

The lightning in our climates may be said to be of different kinds according to its accompanying phenomena. That, which is so frequently seen by night unattended by thunder or any heavy fall of rain, approaches nearly the nature of the aurora borealis. It is the dew of the evening, which serves as a conductor between the earth and the upper regions of the air, or the combination of the fluids in oppositely charged strata of vapour, where the air is too cold or the electric charges are too weak to collect them into clouds. But that frequently seen in the horizon, may be the upper parts of a thunder storm, pouring down its torrents in a distant region, while we have a clear sky. Sometimes in cold rainy weather, especially in the autumn, much sheet lightning is visible by night without thunder; a higher temperature will produce thunder with sheet lightning; and a higher still is necessary for chain-lightning, when the caloric is more condensed. Both the charges which produce the above kinds of lightning are in the clouds. But even in the temperate zones during hot weather, as well as in the torrid, a considerable portion of the negative fluid is contained in the earth. These discharges are generally immediately occasioned by a negative cloud intervening between the charged earth and the positively charged clouds, which completes the circuit. In these cases, there is commonly both thunder and a tremour of the earth, but sometimes only one and at other times only the other: for at the time of union, though the principal combination is at the earth's surface, yet it also extends to a certain distance above and below. This is the *forked* or *zig-zag* kind of lightning, and is the only kind which is destructive. The one fluid ascending and the other descending, or rather the body of the produced caloric, is what we call the *thunder-bolt.*

The electric fluids will not force themselves through the air, except to short distances according to the intensity of the charge; and they always first pass from any prominence or spicula as being the nearst points of the two contiguous charged surfaces: hence we always find that the thunderbolt strikes the very top of the highest objects within a certain distance, as a high tower, tree, or chimney; and as the negative was there collected, the union was at that point and the object is thrown down and shattered to pieces. On this principle it is that thunder storms are the most frequent on hills or mountains; so that mountains, as it were, drain the plains of the electric fluid, a circumstance to which we shall hereafter frequently refer. In

like manner a man may be struck on a wide extended plain, being the highest object; but is perfectly safe when near trees or buildings, unless under them, or so near that his body comes in contact with the circuit or charged surface. But as substances widely differ in their conducting power, lightning occasionally seems to differ from this rule, and lower objects are sometimes struck at a very short distance from higher ones of less conducting power. This has frequently been exemplified in the destruction of cattle by lightning; for red or black oxen have been struck dead in the midst of a herd of white ones that escaped: there is even an instance on record of a red and white ox being killed, whereon the red parts of his body were all scorched, and the white remained uninjured.

Metals are the best conductors of electricity, and of these copper is the first and iron the second. Metallic rods have, therefore, been considered as of use in protecting buildings from the effects of lightning. One end of the rod is elevated a few feet above the highest point of the building, and the other goes into the earth some yards below the foundation. The intention is, to extract the fluid from the clouds which would perhaps come in contact with the building.* When the negative fluid passes through the air from one surface to another, it moves in the form of a star; but the positive, under the like circumstances, has the form of a brush; both appearances have been observed on the tops of thunder rods during storms. To people much afraid of lightning the middle of a room, at the greatest distance possible from all metallic substances, is recommended as the safest; but, undoubtedly, a small house or shed, containing no metal, detached from, but near to the main building, and not overhung by any object, is the most secure.

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* In the mines at Philipsthal, East Prussia, is a curious application of this principle. They make a hole in the rock, and when they see thunder clouds near, they insert the end of a tall metallic rod, and leave it in an erect position all night, when, in the morning, they generally find the rock rent as if blasted by gunpowder.

7. METEORS OR FIRE-BALLS, AND AEROLITES.

THERE are commonly reckoned four sorts of meteors: the *first* or smallest, are of a bluish-white colour, but are peculiarly distinguished by their leaving, as they glide athwart the skies, long tails behind them, which frequently continue for some seconds. The *second* are the most common, being those seen in clear frosty nights with an easterly wind; they have little or no train, and shoot along generally in straight lines obliquely downwards. The *third* sort are larger, more brilliant, and are formed at a less elevation than the above, mostly among the cirro-cumulus, cirro-stratus or in the magazines of thunder: they are generally seen in warm summer evenings, but are mostly the harbingers of stormy or unsettled weather. Their motion is frequently curvilineal; and this, together with their beautiful brightness, often gives them a most splendid appearance.

The above meteors probably originate from the gases and effluvia that ascend from the earth's surface; which being of less specific gravity than the oxygen and nitrogen gases or vapour are floating in the ethereal regions, and being highly charged positive, condense into clouds, and finally into balls: they may be represented in the following manner. In the vacuum of a glass tube, which contains some quicksilver, let there be a moistening of ether, and let the top of the tube be hermetically sealed with a steel cap. Then should the cap be charged positively, while the quicksilver becomes negative by induction, a livid spark will be seen to pass through the ethereal vapour to the quicksilver, thus representing the small beautiful meteors of the first class, which we see gliding about in the ethereal regions far above any clouds. But should a little air be admitted into the tube, then a dense spark of fire will descend to the quicksilver, representing the commonest kind of meteors, or those of the second sort, formed among the cirri clouds. A little more air produces those larger or third kind among lower and denser clouds, such as are seen in thunder storms or previously to earthquakes.

The *fourth* sort called *Fiery Meteors*, are much larger than the above; and have been frequently known to precipitate vast fragments of stones called *Aerolites*, attended with explosions and a sulphurous smell. "Fiery meteors," says Polehampton,

in the Gallery of Nature and Art, "are of all sizes from a small shooting star of the fifth magnitude, to a cone or cylinder of two or three miles diameter. They differ in consistency as much as in dimensions, and in colour as much as in either. They are sometimes a subtile, luminous, and pellucid vapour; sometimes a compact globe or ball, as though the materials of which they are formed were more condensed and concentrated. And not unfrequently they have been found to consist of both, and consequently to assume a *comet* like appearance, with a nucleus or compact substance in the centre or towards the centre, and a long, thin, pellucid, luminous main or tail sweeping on each side. They are sometimes of a pale white light, and other times of a deep igneous crimson, and occasionally irridescent and vibratory. The rarer meteors appear frequently to vanish all of a sudden as though abruptly dissolved or extinguished in the atmospheric medium; their flight is accompanied with a hissing sound, and their disappearanc with an explosion. And the most compact of them, or the nuclei of those that are rarer, have often descended to the surface of the earth, and with a force sufficient to bury them many feet under the soil, generally exhibiting marks of imperfect fusion and considerable heat. The substances in these cases are, for the most part, metalline; but the ore, of which they consist, is no where to be met with in the same constituent proportions in the bowels of the earth.

"Yet however these extraordinary bodies may differ in colour, shape, dimensions, or consistency, they seem to agree with great exactness in their transient appearance, velocity, and elevation when first discovered. It is seldom that they have been capable of being traced longer than from a single moment to two or three minutes; their height has been pretty fairly and concurrently calculated at from fifty to sixty miles above the surface of the earth; and their velocity, from similar calculations, at from twenty to thirty miles in a second; consequently at the lowest computation, exhibiting a rapidity more than ninety times that of sound, and nearly approaching to that of the earth in her annual orbit."

The meteor seen by Dr. Halley in the year 1719 was a globe of no less than 2800 yards diameter. Its altitude he calculated to be about 70 miles, and its velocity about 350 miles per minute. Another of the same kind was seen on the 18th of August 1783 at nine o'clock in the evening. It was first perceived north of

the Shetland Isles. It passed nearly vertical over Edinburgh; and was seen in the south of France, and even as far south as Rome. It assumed different appearances as it went. Sometimes it formed one ball and at other times two or more. At Greenwich two bright balls of about two feet diameter led the way; these were parallel to each other, and were followed by eight smaller ones. Its altitude was about 90 miles, its velocity about 1000 miles per minute, and its direction nearly in the magnetic meridian.

Ancient authors have given accounts of the falling of vast masses of the stones called aerolites; but as they generally considered them as prognostics of some calamitous event, little credit was given to their relations, till like occurrences became so frequent in modern times, that the matter was no longer doubted. In 1803 a shower fell in Normandy, which covered an extent of half a league in breadth, and three quarters in length. Similar instances have occurred both in England and all other parts of the world. The meteor generally distinguished as the Great American Meteor exploded at an elevation of about 17 miles, throwing down a vast mass of stones. Aerolites differ in composition, some are composed entirely of the two magnetic metals iron and nickel;—and occasionally all the magnetic metals, but no other, are found in them. One fell in 1751 near Agram in Croatia, containing 96½ iron and 3½ nickel. A large mass lies in the great Desert of Sahara composed of 96 iron and 4 nickel. An immense mass was found in South America weighing not less than 30 tons, 90 iron and 10 nickel. The composition of one stone was found to be 50 silex, 27 iron, 7 sulphur, 10 magnesia, 1 nickel, 5 loss. But some meteors are merely gelatinous substances; however none of these have been analysed. Red rain has been known to fall in different parts of the world; a specimen of which contained 33 silica, 15·5 alumina, 11·5 lime, 14·5 iron, 1 chrome, 9 carbonic acid, and 15·5 resinous substances.

Philosophers have been much perplexed in endeavouring to account for the origin of these aerolites. We have already stated our conjecture of their cometary nature, (see page 309), and the statements in the above extract from the Gallery of Nature and Art, together with Sir H. Davy's opinion, who supposes them highly ignited bodies moving round the earth in very eccentric orbits, are strong corroborations of our hypothesis. While they retain a certain temperature, it may be

supposed that they have something like a planetary motion; for they are certainly under the influence of the earth's attraction, or, by the earth's progress we might expect to see them left behind, or to have a direct westerly motion, neither of which is the case. But on losing their heat they gravitate nearer to the earth, and the explosion is caused by their shrinking in the act of solidifying. Their motion is generally from north to south or in the magnetic meridian, which shews that they are connected with magnetism: but how, will only be known when the connection between planetary motion and magnetism is rightly understood.

Some philosophers suppose them to have been projected by volcanoes from the moon; others, with more probability, by volcanoes from the earth; while a third class, considering to what height the sands from the Deserts of Africa and Arabia are raised by winds and the electric fluids, as stated sec. 5, find little difficulty in accounting for the siliceous parts of them in this manner. And indeed the sand thus raised, and perhaps by other means, must be very considerable, if it is true as Margray asserts, that every pound of rain water contains one grain of silica. But for the other parts, and especially the metals, we must have recourse to the eruptions of volcanoes. The ashes and other substances ejected from them, such is the quantity of electricity, have sometimes been observed to be collected into clouds, like aqueous vapour, and so pass off to distant regions. Such clouds, far from any volcano, have attracted attention by their uncommon appearance, have suddenly contracted, condensed, and exploded with thunder, and lightning, when they precipitated hot stones. If a steel bar lose weight by magnetism, the highly electrified original particles of the magnetic metals may probably be suspended in the atmosphere; and as we have already supposed positive clouds to pass along the ethereal regions towards the north magnetic pole, these volcanic clouds may be there agglomerated into ignited masses, and as we have already stated, may assume something of a planetary motion.

8. THE PRCIPITATION OF VAPOUR OR RAIN.

We have already, Chap. VI., sec. 10, described the nature of evaporation, and in various places stated that electricity collects the vapours raised by the sun's heat into clouds, or

condenses them much more than the mere buoyancy of the atmosphere is able to maintain. It therefore necessarily follows, that when these electric fluids are discharged in any of the ways we have mentioned in this chapter, these vapours having thereby lost their buoyancy and repulsive property, must condense, or come in contact with each other, and descend to the earth's surface by the mere attraction of gravitation. And as the density of the aqueous particles in a cloud is according to the intensity of the electric charge, and the conducting power of the atmosphere is proportioned to the quantity of vapour which it contains; consequently, where there is the most vapour and electricity, the more suddenly will the latter be discharged, and the more rapidly the former precipitated. Hence it may be determined by the aerial electrometer what quantity of rain will fall, for the aerial charge is always in proportion to the rain. And as the capability of the air for sustaining vapour, and its conducting power are according to its temperature, so in the torrid zone the electric charge is very great, and the rain falling is in proportion; while in the frigid zones the electric charge is very feeble or very much dilated, the rain is very inconsiderable in quantity, and seldom heavier than a haze:—the drops are also in proportion, being in the frigid zones only mere particles, while, it has been asserted, that in the torrid zone they are frequently an inch in diameter.

Though the atmosphere at times contains both negative and positive charged clouds, yet in all heavy rains the chief of the negative fluid seems to be contained in the earth's surface: hence the most rain falls on those parts of the earth's surface, where the electric fluids are the most apt to be condensed, as on sea shores, and in mountainous regions, especially such as are volcanic. The summits of mountains are almost always highly charged, and accordingly, even on some of the British mountains a day seldom passes without rain: hence the enormous quantities sometimes precipitated against ridges of no very great height: see Chap. VII, sec. 9. The most elevated of the Andes protrude their summits far into the regions of the positive clouds, being volcanic and highly charged negative, they completely drain that part of the atmosphere of the positive fluid or clouds: so that on the plains of Peru and Chili, which lie between these mountains and the Pacific ocean, it never rains—no combination of the electric fluids, at least by day, taking place in their zenith. But as the evaporation from the western

ocean, attracted by and precipitated on these mountains during the day is very great; and as a wind always blows from a negative surface, as from the tops of the Andes, which in the absence of the sun is excessively cold; so by night it meets some of these vapours on their passage, condenses them or otherwise precipitates them as dew and fertilizes these plains.

Many heavy rains, even in Britain, have been attended with something of a volcanic nature. A remarkable instance occurred about 6 o'clock P. M. 2nd of last September (1824). On a part of the Pennine chain in Lancashire, two immense bodies of muddy water issued from the earth and did much damage in their course. "At the time of the eruption, the clouds were copper coloured, gloomy and lowering; the atmosphere was strongly electrified, close and sultry, and there was loud and frequent thunder, preceded by much zig-zag lightning, flaring and vivid. An hour before there was scarcely a breath of air stirring, but the wind quickly rose almost to a hurricane, and after blowing hard from 6 to 8 o'clock, sunk again into a profound calm; at which time the heavy rain, which had continued all the while, ceased, and with the exception of a few floating clouds the sky was nearly serene." The storm extended into Northumberland, and gave the inhabitants of the intervening part of the country a specimen of what thunder storms are in hot climates. The noise in the air was like the roaring of the sea in a storm, but much louder; and the lightning was as if the clouds were on fire—the sheets extended to the ground. At Denbigh, July 16th, 1706, during a heavy fall of rain, attended with a terrible noise like thunder, wind southwest, water broke out of the earth in many places, and caused the overflowing of the rivers of that and the adjoining counties, and in many cases changed their course. Many other instances are on record.

9. HAIL.

HAILSTONES are of various sizes, from the mere particle of snow to a large mass of ice. The centres of hailstones sometimes consist of soft spongy snow, while the outsides are clear ice. They are occasionally in the shape of oblate spheroids, so that they must have had a rotatory motion in their descent and at the time of their congelation. But they assume various figures, being sometimes round, at other times pyramidal,

cuniated, angular, thin and flat, and occasionally stellated, with six radii like the small crystals of snow. Hail and dry snow are generally positive, while rain water is mostly negative.

Hail is merely frozen rain, and the only difficulty in its natural history, is, to account for its congelation. All the great falls of hail have been attended by thunder and lightning, and on all occasions when there is hail there is great conflicts among the clouds, so that we consider hail, in some degree, as the produce of the same aerial or electric process as that of waterspouts. In this manner the vapours are kept suspended by the intensity of the electric charge and the whirling motion, with a much greater degree of density than they ever have in clouds; and are also, by the conflict caused by the combining electricities, carried into more elevated regions than the cumulo-clouds ever ascend to, and thus enter the regions of perpetual congelation; so that they are there solidified into those icy masses, of which natural historians give many surprising accounts.

In Italy, 1210, there fell a shower of hailstones of enormous size, some of them weighing an hundred pounds. It was attended with a strong smell of sulphur, and the stones were of a bluish colour. Another fell at Lisle 1786 of a large size, some of them in the middle contained a brown substance, which exploded in the fire. April 29th, 1697, a large black cloud from Caernarvonshire passed over Cheshire and Lancashire, which threw down hailstones of half a pound weight:—its track was 60 miles in length and 2 in width. May 4th, in the same year, a shower fell in Hertfordshire, wherein were stones of fourteen inches in circumference:—they killed several persons. But there are records of masses of ice that have been precipitated from the atmosphere, or thrown down by waterspouts.

10. SNOW.

When the flakes of snow are carefully examined with a microscope, they appear to be composed of ice as perfectly crystallized and as pellucid as that formed on the purest water. They, for the most part, are in irregular figures, in the shape of rowels or stars with six points. On each of these points are other collateral points, set at the same angles as the points themselves; among which are irregular or fractured ones. But on some occasions, when the atmosphere is less settled, they seem as if they had been carried about by contending winds, or

as if half thawed and again congealed; so that, when they descend, they have somewhat the appearance of icicles, and sometimes they approach very near in shape to hailstones.

In the neighbourhood of lofty mountains, the flakes of snow or half hail generally have a peculiar conformation. On these occasions the snow proceeds from more intense discharges of the electric fluids. But sometimes the aqueous particles seem to be precipitated from the atmosphere, by reason of its loss of temperature; when the conducting power is so diminished that the electric fluid is too much dissipated to give the repulsive property and consequent buoyancy to the air and vapours, so that the latter collapse, congeal, and become too heavy for the air to sustain: and coming in contact with each other in their descent, they adhere and form the flakes: hence the more elevated the cloud the larger the flakes of snow. On such occasions there may possibly be a fall of snow without any combination of the electric fluids, but the quantity must be inconsiderable; however on most occasions, and especially when the fall of snow is great, it is occasioned by the contact of differently electrified clouds with the discharge of the fluids.

11. WIND.

We have already explained two classes of *winds*, viz. those depending on the rarefaction and condensation of the air by the presence or absence of the solar rays; which winds are regular; and those depending upon the loading and expansion of the atmosphere with vapours, and its concentration by their precipitation in rain: but though the winds of the first class are considerable, yet neither class perhaps ever extend to what we call a tempest. The origin of all storms, and of most of the irregular winds we have yet to develope; however we have sufficient data in the electric principles to set this long agitated question at rest.

The atmospheric pressure, as indicated by the barometer, will sometimes vary one-tenth, that is, the mercury will rise or fall about three inches, or one-tenth of its height. Suppose then a fall of six inches in depth of rain, which is perhaps as much as ever falls in one storm in our climate;—this is only equal to a sixteenth part of the whole weight of our atmosphere, which balances 30 feet of water. But as vapour is one-sixth lighter than atmospheric air, it would be equal in bulk to one-

fiftieth part of the whole atmosphere. These six inches depth of rain, therefore, being precipitated, would only make room for air equal in weight to one-fiftieth part of the atmosphere, while perhaps the barometer shews that five times as much weight is acquired, for it has risen three inches or one-tenth of the whole, between the commencement of the storm, and the time when the sky became serene and clear. But as the air was of the same altitude or bulk before the storm as it is after it, (for how much vapour soever there may be in the atmosphere it always increases its extent in proportion to its bulk, or displaces an equal bulk of atmospheric gases,) consequently, there can only be the difference between the weight of this vapour and a corresponding bulk of atmospheric air, which would be equal to only a three hundred and sixtieth part of the whole; and which would cause a rise in the barometer of only a twelfth part of an inch instead of three inches: so that the mercury would rise 36 times as much as the mere fall of rain would allow it.

Now as each electric fluid is repulsive of itself, when the particles of the atmospheric gases, and those of the vapour are charged they must repel each other, or the whole of that charged portion of the atmosphere will have its expansive property very much increased; and as we have shewn that clouds owe their existence to the electric fluids, it is very evident, that when the earth's surface contains a very high charge of the negative fluid, and the atmosphere is loaded with very highly electrified clouds, perhaps both positive and negative, the air and vapour from the very ground to the ethereal regions must be very much rarefied over that portion of the earth's surface. It is not perhaps too much to suppose that the atmospheric air, by these intense electric charges, is over a very extensive area increased in bulk or rarity nearly one-tenth as above described; and here we have the foundation for hurricanes, tornadoes, and storms of every description. For as the air thus increases in bulk, it must extend laterally so as to find its own level; but this motion will be slight in comparison of that occasioned by the discharge of the electric fluids, and the consequent immediate precipitation of the vapour which they suspended, when a vacuum will be made equal to more than one-eighth of the atmosphere; and the surrounding air rushing in to fill up the vacuum or restore the equilibrium, will be the destructive wind.

Now if the electric fluids were all discharged at one shock, and the vapours precipitated at one splash, the air, rushing together to restore the equilibrium, would move with one eighth of the whole atmospheric pressure. And as this is equal to 15 lbs. to a square inch or 2160 lbs. to a square foot, the wind would move with a pressure of 270 lbs. to every square foot of opposing superficies. But this is never the case, for the atmosphere of our climate is mostly three or four days in discharging its load; and in the torrid zone, hurricanes or tornadoes are generally some hours in spending their fury. It has been proved by experiment, that in a hurricane the wind moves with a velocity of 100 miles per hour, and a force or pressure of 49 lbs. to every square foot of opposing surface. When it moves at the rate of from 30 to 35 miles per hour, it has a force of 5 or 6 lbs. to each square foot. From 10 to 15 miles per hour its force is 8 oz. or 1 lb.; but when only 4 or 5 miles, which is a gentle breeze, its force is from 1 to 2 oz. Now as a middle sized man presents about 15 square feet of surface to the air, and weighs about 160 or 180 lbs; supposing the wind to blow against one side of him or half of his surface, in a hurricane he will be propelled by a force of between two and three times his own weight; even when the wind presses with a force of only 10 or 12 lbs. to the square foot, it will equal his weight. From this calculation we may conceive how hurricanes are so very destructive,

Now the charging of the air, and perhaps we might say the locomotion of the electric charges, as from one mountain or one island to another, must often cause great agitations in the atmosphere; and here perhaps we may have the origin of squalls and sudden gusts, which in some regions are so frequent, and which are often unattended by any discharge of the fluids in thunder and lightning, &c. Hence whenever we see a black cloud sailing across the sky, it is mostly preceded by a strong wind, and not unfrequently followed by one. For though the air on the front is expanded and pressed out, yet that in its track is rarefied, and pressed upwards by the contiguous uncharged air, so that there is a lateral current to fill up the vacuum. Such clouds hovering over the sea, in volcanic regions, often cause an agitation in the water similar to the swell of the tide. Besides, clouds often descend vertically, by their own presence charging the air positively; and as they never thus descend but when the corresponding negative charge is in the earth, so the lower regions of the air become negatively charged.

In the volcanic districts of Italy and the Archipelago, such occurrences are very common. Sonnini describes them as follows: "Above the high mountains, of which the coast of *Caramania* is for the most part formed, it is not uncommon in clear weather, to see a very small black cloud, frequently no bigger in appearance than a bird. This globe of vapour is extremely agitated; at first very small, it spreads all of a sudden, contracts, appears, and disappears at intervals above the mountain, and changes its form every instant. How calm soever the atmosphere may be, a sudden and violent squall may be expected. At the sight of these insulated clouds, which discharge the wind with so much rapidity and vehemence, that if a ship be not prepared for being overtaken by it, she runs a great risk of losing part of her sails and even her masts and yards. On the 28th of October we experienced one of these sudden squalls, after a calm which had kept the ship stationary abreast of Cape Crio, a large promontory of Caramania. During this calm, a numerous shoal of fishes, cleaving the water level with the surface, and even darting above it, passed close to us with great rapidity; and the agitation of these inhabitants of the depths of the sea is always a certain presage of an approaching and violent agitation of the atmosphere and waters. A small cloud, the precursor of the storm, had made its appearance above the promontory; it expanded, and we were overtaken by a gale of wind, which compelled us to take in our sails, and continue lying-to during the whole night, tossed about by short and overgrown billows." Bruce mentions such clouds and storms as of daily occurrence in Abyssinia.

Hitherto we have only described the central part of storms, or the commotion in that part of the atmosphere which contained the electric charge; but it is evident the motion must be communicated, according to the violence of the storm, to a great extent and circumference. Dr. Franklin took a great deal of pains to investigate this matter in a storm or hurricane which occurred in America. The central part or hurricane he found to have been in a mountainous region, (the mountains of the United States though low are chiefly primitive,) and that at a certain distance, the winds blew to this region as a centre of motion, thus forming a circle;—and the radii he found to be about 100 miles, beyond which distance the wind, if any, was not more than a gentle breeze. The small hurricanes or tornadoes of the East Indies extend over a diameter of about 120

miles. The aurora-borealis we have described as a discharge of the electric fluids, and though the charges are less intense than in the warmer climates; yet they are extended over a much larger space, and the fluids seem to be equal or even more abundant in quantity: consequently, it is remarked, that the *northern lights* are always succeeded by a southerly wind. When they have been very brilliant, this wind becomes a tempest; a circumstance well known to mariners who traverse the Atlantic ocean in the latitude of Europe.

Should the nucleus of the storm or the union of the electric fluids be eastward of us, we shall have a west wind. If S.E. a N.W. On the contrary, if the union be to the westward, we shall have an easterly wind; if it incline to the N. the wind will incline to the S. and if S.W. then the wind will be N. E. Should we be near the combination, we shall not only have a strong wind but rain too; and if at the centre, we shall have a calm, occasionally interrupted by sudden gusts, blowing in various directions. When in a strong wind we see the clouds collect to leeward, we may then conclude that the place of union is fast advancing towards us, and may be sure that a calm and rain will shortly follow. Also in a calm with heavy rain, when the wind begins to blow, we may conclude that the storm is either spent or its nucleus is receding to a greater distance, and that we shall shortly have fair weather. When we find the wind varying and without rain, as it frequently does when the electrified vapours are merely collecting, at which time the mercury in the barometer falls, we may expect rain. But although a great part of the materials of the storm may be collected around us, and the weather-glass may be very low on the eastern coasts of the island for instance; yet the whole may be discharged on the primitive and transition mountains of the western side, when we shall only have a brisk easterly wind.

As the electric charges are principally among the vapours, which are thus collected into clouds, the air therefore in winds caused by a distant storm, may not exhibit any signs of electricity; but as on such occasions the positive clouds are gathered from an immense distance, hence previously to strong winds we may frequently see a very rapid motion of the clouds, while the air at the earth's surface is still.

Hurricanes, we have already said, are always to be found among primitive mountains, or such as exhibit something of a

volcanic nature. In the East Indies they are said to occur once in five years :—perhaps the earth is capable of holding no more than is collected in this time. In the West Indies where tornadoes prevail, they have no hurricanes; and it has been remarked in Jamaica, that when they have wind they have no hurricanes;—these, in both cases, discharging the electric fluids before they attain sufficient intensity for the more violent paroxysms. Hurricanes also generally occur about a month after the sun has left the zenith : the direct solar rays, increasing the conducting power of the atmosphere according to the heat, and also the moisture which prevails at this time, liberate the electric fluid from the earth; but when he retreats, the earth's surface becomes dry, and the air loses its conducting power, and then the electric fluid rapidly accumulates.

The Storm Glass is a curious contrivance for exhibiting the intensity of the electric charge of the earth's surface, and the consequent change of weather depending thereon. Take two drachms of camphor, half a drachm of purified nitre, and half a drachm of purified ammonia, pulverize them, and dissolve them in two ounces of proof spirit. Put the mixture in a glass bottle or tube about ten inches long and three-quarters of an inch diameter, the mouth of which must be covered with a piece of bladder, perforated with a needle; then hang it up against some *conducting* substance that communicates with the ground. When there is no electric charge in the earth's surface, which is the case in fine, calm, and settled weather, the solid matter of the composition subsides to the bottom of the tube, and the liquid remains clear. But when a charge begins to collect previously to a change for rain, the compound gradually rises, and small stars float about in the fluid, which however still continues pellucid. Twenty-four hours before a storm or very high wind, it will be partly on the surface of the fluid apparently in the form of a leaf, while the fluid is thick, and as if in a state of fermentation. During winter, when small meteors are gliding about in the ethereal regions of the atmosphere, and especially when white frosts or snows prevail, the composition is remarkably white, and somewhat higher than usual; while in fine hot weather in summer, it subsides closely to the bottom. Lastly, as the composition is charged negatively, it will be repelled from the nucleus of the earth's charge, or that point towards which the wind will blow; and will consequently be

arranged chiefly at that side from which the wind will rise, so that we may always know where the storm will be the most severe,

12. ATMOSPHERIC TEMPERATURE.

We have already described the primary laws of atmospheric temperature as depending on the rays of the sun; and offered some observations on the nature of the earth's surface with respect to generating and absorbing heat. We therein referred to the excessive cold that prevails on the tops of high mountains, which perhaps may seem to vary from what we have now to state, viz. that bodies electrified negatively are heated more rapidly when exposed to the solar rays, than when they are either not charged or charged positively. Now the summits of high moumtains are almost always charged negatively, while the adjoining valleys are in a state of indifference :—it might therefore be expected that the tops of mountains would acquire a much higher temperature than the valleys, but we find the reverse to be the case. However this by no means affects the stability of our theory; for, was the atmospheric air of the same density on the summits of mountains, that it is at their feet; and could we prevent the circulation of the air, as it is prevented on the side of the mountain and the plane of the earth, we should then have our full proportional increase of temperature.

To determine this question, M. Saussure instituted a set of experiments upon the Alpine mountains near the lake Geneva, and ascertained that a body at an elevation of 1670 yards, when exposed in the open air to the sun's rays, lost 14 deg. of temperature; when partly exposed, it lost 6 degrees; but when entirely defended from the circulation of the air, and exposed to the full solar rays, it gained one degree of thermometric heat, and that without making any allowance for the aerial rarefaction of this elevation. May not the very radiant appearance, which the summits of some of the lunar mountains present, be partly owing to something of this kind?

Atmospheric temperature depends a great deal on the winds. The earth is negative, and a positive wind therefore produces heat; for not only does the positive fluid unite at the place where we are, and produce caloric around us, but the wind also brings that which it has created to the windward of us, brushing it over

the face of the earth; and as the positive wind is generally from the south, so a south wind is proverbially warm. On the same principle a north wind is synonymous with cold, since it is a prevalence of the same fluid with that of the earth, and can produce no caloric. The temperature of the collateral winds must be very various. For while a south wind is positive and the north negative, the winds from due east or due west will sometimes be negative and sometimes positive; and at other times the wind will be from these points when the outskirt of the union is there, the centre being at the contrary side of us; therefore, not only the winds from the east and west, but also from the adjoining points of the compass will be extremely various as to temperature, just as the one or the other of the fluids prevail.

The above theory will explain a number of circumstances respecting the *weather*, and enable us to discover many prognostics of its changes. We frequently have a northern, cold, frosty wind in the morning, which, in the afternoon, is succeeded by a warm south wind. The negative fluid of the earth had accumulated in the lower regions of the air during the night, so that the union of the two took place to the south of us, but by the rays of the sun the positive is reinforced, and this place of union recedes northward.

The air is almost always colder at sun-rise than at any other time, so much so that we frequently have a smart frost, when all the night has been comparatively warm. Now the electricity of the earth's surface is weakest during the night, becomes stronger at sun-rise, and increases through the forenoon in proportion to the positive fluid, as stated in sec.1. Here we have the cause of the cold which prevails at sun-rise. No sooner do the solar rays come within a certain distance of us, or strike the upper regions of the air, than electricity is excited, that is, is drawn off from the earth to meet the solar rays in the higher regions of the atmosphere. The air at the earth's surface is therefore rarefied by becoming charged with the negative fluid, and rarefaction always produces cold. Though this extrication of the electric fluid increases through the forenoon, yet the solar rays still advancing cause the union to take place on the surface of the earth, so that what caused cold before, now produces a proportional quantity of heat. As the electric charge of the earth is continually varying, when the charge is greatest, this morning cold will be in proportion; consequently, we frequently

have, on such occasions, a smart hoar-frost, followed by a scorching sun. But when the earth is thus charged, the atmosphere under the sun is positively charged, and therefore, when he advances towards the meridian, the charges begin to unite: hence we almost invariably find, that such frosts are succeeded by rain in some part of the day.

On the last stated principle depend a number of curious phenomena. Many caverns are very remarkable for being warm in winter and cold in summer—we do not mean comparative temperature, but real. For some, during summer, are hung with icicles, while their temperature in winter is far above the freezing point. Now in winter the atmosphere generally abounds in negative clouds and the principal combination is in the lower regions of the air, while in summer the negative fluid is principally in the earth, and the combination is at the surface; the surface of the earth or summit of the mountain immediately above these caverns is in summer charged negatively, while in winter it is not so. Now these caverns are in mountains where rents by subsidences have taken place; and as we have stated page 410, that the earth's internal temperature increases as we descend, so these caverns attain somewhat of this temperature in winter, while in summer it is carried off, if not by the passage of the electric fluid, it is by the great heat, (produced on the surface, both by the rays of the sun and the contact of the positively charged air,) and the consequent great evaporation as stated at page 136. On the same principle, in certain states of the atmosphere, we find it a great deal colder in the house than in the open air; or, within doors, where there is not a large fire, we have a cold raw air; while out of doors, is a fine, warm, fresh breeze. On this occasion the house is charged negatively, and the electric fluids combine on the external surface; and thus the inner rooms become like the caverns in summer. Also, when the atmosphere contains vertical negative clouds, or the lower regions of the air are negative we always have cold weather; hence the cold that precedes earthquakes. While in summer or in clear weather, when a positive cloud passes the zenith, the thermometer immediately rises a degree or two. So likewise when the air is charged with positive clouds, we have close and warm weather; if in summer as before thunder, it is hot and sultry. But when the fluids are discharged as after rain or thunder, we always have, if the atmosphere is perfectly exhausted, a clear air, with a bracing wind.

It is a well established fact, that the climate of Europe has undergone a considerable change within these two or three last centuries;—the winters are not so severe, and the summers are not so hot. Now about 160 years ago, the magnetic pole was directly north of us; and in the two or three preceding centuries, it was traversing the northern parts of Europe. We have already stated our supposition, that positive charges pass from the torrid zone, and consequently negative also by induction, and are concentrated around the north magnetic pole; now should this be the case, there would, then, be more negative electricity in the lower regions of the air in winter, and more positive in summer, and we should have the above stated extremes of temperature. The north magnetic pole has now emigrated to North America; and our hypothesis requires, that we should find the same effects, at present, in that continent, which we suppose it to have produced in Europe. The one extreme viz. the severity of winter, requires no comment, for it is amply established; and there are, we think, sufficient data to account for the heat of summer not corresponding thereto.

In Chap. VII. s. 12, we stated the great inequality, between the temperatures of the two continents, and described the intensity of cold that reigns in each extremity of the American continent. Now, when the nature of the surface of each continent is examined with reference to the electric principles, we shall find sufficient cause for the excess of cold in America. All the eastern parts may be generally considered as consisting of the summits of primitive mountains, while the western side contains the most elevated and most extensive range of volcanic mountains in the world: consequently, the electric fluids must abound much more in the atmosphere of this continent, than on the old continent, which has two thirds of its surface composed of secondary formations: and therefore the climate must occasionally be much more intensely cold. To begin with the southern point of America: the island of Terra del Fuego, and around the Straits of Magellan, is one scene of volcanic ruin, named by Cordova, "The Ruins of a former World" and by others the "Desolation of the South." Even in summer, it is not uncommon to pass 15 or 20 days together without a sight of any heavenly body; while a storm is perhaps all the while breaking on the summits of the mountains. And throughout the whole range, the Andes are continually attracting the positively charged clouds, and exhausting the atmosphere of the positive

fluid;- -and here are hurricanes continually spending themselves, while the mountains are also occasionally charging the air negatively, and dispersing it in cold gusts to the lower regions. The lower regions also, as throughout Brazil, and the United States are principally composed of primary districts, which develope a great deal of the negative fluid, while the positive is drawn off to the Andes. In the torrid zone, these currents of air, thereby occasioned, are called refreshing breezes; but in the temperate zones, they are the promoters of intense cold.

High trees, with which America abounds, have a great effect in emptying the atmosphere of the positive electric fluid. As storms are perpetually spending their fury on the summits of the Andes; so in the woods, at the greatest distance from these mountains, it thunders almost continually. In Guiana the rainy season has been shortened, and the warmth greatly increased by cutting down the woods. Vegetables, as explained in Chap. XVIII. also, independently of the above process of serving as conductors, exhaust the air of the the positive fluid: hence the wind is always colder to the leeward of plantations than to the windward. But as this superabundance of the electric fluids will occasionally cause a corresponding increase of temperature where the soil is cultivated, so vegetation in some parts of North America is often much more rapid than in Europe. But as the hottest day will be when the negative fluid most abounds, to the northward; so during the absence of the sun, a stream of air will sometimes rush southward, producing a frost that ruins all the produce of the preceding fine weather.

The above will appear in a stronger light if we take a view of some of the winds which accasionally prevail on the old continent; where instead of an elevated range of volcanic mountains, and a surface of primary formations, interspersed with forests of tall trees, we have a desert of burning sands. Here, in the first place, we find the wind, called the Harmattan, blowing from the African Desert. Instead of the air taking up a load of vapour wherein the caloric becomes latent, it elevates a quantity of dry sand, which obscures the sky and causes the sun, when viewed through it, to appear as shorn of his beams, and of a violet colour. The violence of the heat is said to be equal to that of an oven when the bread is withdrawn; and so dry is the wind, that it parches and shrivels up the skin; water sprinkled on the floor is evaporated in a few minutes, and plants are immediately stripped of their verdure. This wind, is in Egypt,

called the Khumseen or wind of fifty days; because it blows in the fifty days immediately after the sun has come to this side of the equator, or rather because they suppose it precedes the overflowing of the Nile by fifty days. It always blows from the south; its motion is rapid, but it is not very hot till it has continued for some time. It usually lasts three days; but is altogether insupportable if it continue beyond that time, and it is the most dangerous when it blows in squalls. The Harmattan on the Gold Coast is represented by some as very salubrious, by others as the contrary. When the atmosphere is dry, and it blows over a dry surface, this wind is positive, that is, the negative keeps beneath the surface of the earth; and on this occasion the wind is salubrious; but on the contrary, when it is attended by rain or fog, or it blows immediately after rain, or over marshy grounds and moist situations, then, the negative fluid is no longer beneath the earth's surface, but charges the lower regions of the air, which becomes very pestilential. See Chap. XX. s. 6.

But the above wind sometimes assumes a more hideous form, and moves with a more deadly effect; for its electric charges are occasionally concentrated to a focus, when it constitutes the *Simoom*. This phenomenon seems to be akin to our whirlwinds, and is a column of the positive electric fluid moving from the S. or S.E. northward, and is so concentrated that it is almost sure death to those who breathe the baleful air it moves in. When its terrific form glides across the desert, there is no means of avoiding it, since it moves nearly as quick as lightning. The only chance of escaping it, is, for the traveller to throw himself flat on his face, which he has not always time to do. But Bruce's ardent mind was not to be diverted from the attainment of knowledge by the presence of danger. On the attendants calling out that the Simoom was coming, he immediately turned for a moment to the quarter whence it came. It resembled a haze, in colour like the purple part of the rainbow, but not so compressed or thick; it was a kind of blush upon the air; and was about twenty yards in breadth and about four from the ground. Its motion was so rapid that before he could turn and fall upon the ground, he felt its violent heat upon his face. It passed like a gentle ruffling wind, but was succeeded by a slight breeze, which for two or three hours, was of such intensity of heat as nearly to suffocate them. Bruce unfortunately inhaled a little of the purple haze, which nearly deprived him of his

voice, and caused an asthma of two years' continuance. They saw it twice afterwards as they journeyed across the desert. The second time it was more southerly, its edges were less defined, resembling a thin smoke, and it had about a yard in the middle tinged with purple and blue. The third time it had the same purple and blue appearance, but was preceded by the largest sand pillar they had seen.

The *Samiel*, or *Samyel* is a still more deadly blast, and seems to be a body of the negative electricity. It is peculiar to the desert of Arabia, coming from the N.W. and usually occurs in the months of July and August. Some years it will blow 8 or 10 times, and in others not at all. It often passes with the quickness of lightning; seldom continues more than a few minutes; and sometimes extends to the very gates of Bagdat, but never affects any one within the walls. The only warning of its approach, is, when with a clear sky, a thick blue haze is seen rising out of the horizon. It is said to leave a sulphurous smell behind it. When the Arabs or Persians see it approach, they throw themselves flat upon their faces on the ground; and when it is over, which is almost in an instant, they get up and look about for their companions. If any one be motionless, they take him by a leg or arm, and jerk him with some violence, when, if he has had the full force of the blast, the limb separates from the body; if not, animation is generally restored by forcing perspiration. With such a wind, it is supposed, Sennacherib's army was destroyed. See 2 Kings, c. 19, v. 35, and Isaiah, c. 37, v. 36.

But independent of the above winds, whose general direction seems to have some connection with the magnetic meridian, the volcanic districts have winds peculiar to themselves. There is a remarkable wind, mentioned by Bakewell, occasionally blowing from a certain part of Cross Fell. It appears as if it issued from the internal parts of the mountain, is attended by a roaring noise, blows towards the lower regions, and is always cold and very disagreeable. Such winds are common among the Alps, and in other primitive districts; and are most probably occasioned by the great quantity of the negative electric fluid, which abounds in the summits of the mountains, and which charges the air, and disperses it around. The *Sirocco* prevails in Italy, Sicily, Greece, and Indostan, all which districts are volcanic. This wind seems positive, and is the air attracted at certain seasons when the negative fluid most abounds in the

summits of these mountains, towards these negative regions. It is not found on the Mediterranean, but is often very bad at Palermo, though much worse at Naples. All these mountains, both throughout Europe and Asia, have their periodical winds, which are at certain seasons negative, and at others positive; when they blow in different directions. They are always disagreeable, but are occasionally pestilential.

From April to July, two very extensive strata of clouds, are seen to pass over Upper Egypt in opposite directions. The one is negatively charged, and passes from the north to the regions of Abyssinia; where its vapours, being precipitated by coming in contact with the positively charged clouds of the torrid zone, cause the overflowing of the Nile. On the contrary, the upper stratum is positive; and is attracted from the torrid zone to the mountains of Armenia, which are a range of volcanic productions, and are always therefore charged negatively; its load of vapours is, consequently, thereon precipitated, which causes the periodical overflowing of the Euphrates, and some minor rivers, that have their origin among these mountains.

The above shews the utility of mountains, hills, and trees, so as to form the electric circuit; for though in America there are too many trees, so that the air is too much exhausted of its positive fluid, yet in Africa where there are none, the positive continues at so great a height that the air retains its vapour. And though there are negative clouds over the Egyptian plains, yet these do not present such a concentrated charge to the upper stratum as that mustered on the summit of a hill, which will sometimes cause positive clouds to descend vertically from the highest regions of the atmosphere. A whole stratum, therefore, of such clouds may be attracted downwards by a negatively charged island; but will be made to precipitate their vapours more copiously in particular places, by the agency of hills and trees, which act as the metallic spikes in the prime conductor.

CHAP. XVII.

Vegetable Substances.

1. Organized Bodies. 2. Vegetable Productions. 3. Fermentation. 4. Distillation.

1. ORGANIZED BODIES.

We have hitherto been treating of mineral substances, and such combinations as are effected by the mere electric energies; it remains that we should now examine *Organized Bodies*, that is, such substances as are not merely formed by the above energies only, but are also elaborated by another principal, viz. Life. This imposes on the electric energies new regulations, apparently causing them to form disproportionate combinations, or, in some instances, to suspend their powers: hence the rapid tendency of some organic bodies to decomposition as soon as the vital principle becomes extinct. What this new principle is, we cannot even form a conjecture, much less are we able to explain. The only thing, therefore, aimed at in the following pages, is, to point out its connective medium with matter, its channels, its instruments; and, in some cases, the manner in which it flows along the channels, and uses the instruments so as to form that medium.

Organized bodies are divided into two classes *animal* and *vegetable*. They are said to be organized, because their component materials are so disposed, that innumerable channels are found among them, along which fluids pass either to convey a fresh supply of materials to enlarge the body, or, to carry off

such particles as have performed their office. The main-spring of this circulation is *Life*, which generally has its principal seat at some central part, whence the channels proceed that maintain a communication with the whole. When life quits its residence, this circulation ceases; or when this circulation is stopped, by cutting off the circulation between its parts, then life also becomes extinct.

All substances are divided by Naturalists into three kingdoms: mineral, vegetable, and animal; and Linæus thus distinguishes them: stones *grow;* vegetables grow and *live;* and animals grow, live and *feel.* How far stones may be said to grow may be judged of from some of the preceding chapters, especially Chap. XII. sec. 15; from which it appears, that the word *grow* as applied to stones or minerals, only means an external enlargement, or encrustation, without any communication with the internal parts.

2. VEGETABLE PRODUCTIONS.

It might seem the most natural plan to begin with soil, or the pabulum of plants and thence proceed to their germination; but experience will prove that the best method, is, first, to treat of their elements; then, the compound substances found in them; afterwards, their decomposition, and the various substances formed thereby; and lastly, to offer such remarks respecting the laws of vegetation, as philosophy has enabled us to make.

Vegetables are principally composed of the three elements,—oxygen, carbon, and hydrogen. In the green state and in the pulp or pericarp of fruits, oxygen prevails; but when ripe, or dried, and in all seeds, carbon is predominant. But besides these, there are several of the other simple substances casually found in the vegetable kingdom: of these nitrogen is perhaps the chief; iodine occurs only in marine plants; sulphur and phosphorus are generally met with, combined with lime, which is the most abundant of all the earths: silica exists only in the epidermis of some plants; alumina very rarely enters into the composition of vegetables; and magnesia, though it abounds in some marine plants, is very uncommon. Of the alkalies, potas is found in most inland plants, especially in the buds and young leaves; while soda chiefly occurs in such as are of marine origin. Of the metallic oxides, iron is the most abundant, the

ashes of oak contain $\frac{1}{12}$ of it; the oxide of manganese is also frequently met with. But all of these are perhaps never found in the same plant; some plants contain one, some another, and the quantity of each frequently varies in the same species of plants growing in different soils. *Garlic* seems to contain as great a variety as most plants: when burnt, it leaves about one-eighth of ashes—and in 172 parts of these ashes the following ingredients were ascertained: potas and carbonate of potas 33. Sulphate of potas with some muriate 58. Alumina 2. Phosphate of lime 15·5. Oxide of iron 1·5. Magnesia 9. Lime 14. Silica 8. When distilled with water, garlic yields a liquor that acts as a blister.

The substances called *vegetable productions* are such as are compounded in plants, in which they are found while growing; when ripe, or when cut and dried, the principal of them are the following: 1. Sap. 2. Mucilage. 3. Sugar, honey. 4. Fecula, starch. 5. Gluten. 6. Fixed oil. 7. Volatile oil. 8. Camphor. 9. Resin, wax. 10. Gum-resins. 11. Balsams. 12. Gum-elastic. 13. Extractive or colouring matter. 14. Tannin. 15. Woody-fibre. 16. Vegetable acids, with several others that might be particularized.

1. *Sap.* This is the most important substance in the vegetable economy, since it is the vehicle of all the materials that form the plant, performing nearly the same office as blood in animals. It principally consists of water and carbonic acid, which rise from the roots to the branches and leaves, charged with the bases of all the earthy substances found in the plant, and which the roots pump up from the soil. It is ascertained that sap never descends. The various organs of the plant secrete the hydrogen and carbon of the water and acid, which are decomposed by the vegetative process; elaborate them with their other ingredients into their composition, and send forth the superfluous oxygen as gas to renew the vital air of the atmosphere. The composition of sap must therefore vary in different plants, as well as in the same species of plants grown in different soils.

2. *Mucilage*, mucus, or gum is a glutinous matter, secreted from the sap; and when in excess, exuding from trees and hardening by evaporation upon their outsides. Almost all fruit trees, but especially the plumb, yield some sort of gum. But that which produces the *gum arabic* is a species of the acacia growing in Arabia; it is also procured from a species of the

mimosa, particularly the *nilotica*. The natives make incisions in the bark, and obtain a large quantity, which forms a great part of their food and a considerable portion of their commerce. It is composed of 23 carbon, 11 hydrogen, 65 oxygen, 1 nitrogen, with a little phosphate of lime.

3. *Sugar*, though ready formed in some plants, is not found in a simple state, but always mixed with gum, sap, and other ingredients. It is to be met with in every vegetable, but abounds the most in roots and fruits, yet the stem of the sugar-cane contains more than any other plant. Sugar has been obtained from parsnips, carrots, the beet-root, and all sweet roots; but the process is tedious; the quantity obtained, small; and it always retained a peculiar taste. The composition of sugar is 64 oxygen, 28 carbon, 8 hydrogen. *Honey* is a mixture of saccharine matter with gum.

Sugar is obtained from sugar-canes by bruising them, and pressing out their juice between two iron rollers. The juice is then boiled with lime water, which causes a scum to rise to the surface, and the clarified liquor is let off below, and evaporated to a certain consistency. After which, it is suffered to cool and crystallize in a vessel with a kind of filter at the bottom to permit the syrup to drain off. It is now *muscavado*, moist or brown sugar; and the syrup is called *molasses* or treacle. It is farther refined to convert it into lump-sugar. This is done by dissolving it with water, and blending it with albumen, an animal substance chiefly found in the white of eggs and in blood, so that eggs and bullock's blood are mostly used for this purpose. The albumen combines with all the solid impurities of the sugar, blood, &c.; and rises with them to the surface, where the whole is skimmed off, and nothing remains but a clear liquor consisting of pure sugar. This liquor is again evaporated to a proper consistency, and poured into moulds, in which, by a confused crystallization, it forms *loaf-sugar*. But another process is still necessary to whiten it. For this purpose, the open or wide end of the mould is closed with a layer of pipe-clay upon the sugar, through which water is made to trickle slowly, and, passing through the sugar, it carries off the colouring matter. Evaporation was once effected by heat alone, but now it is principally performed by immense air-pumps, worked by powerful steam-engines, assisted only by the heat procured from steam.

4. *Fecula*, farina, or flour is the general name given to the farinaceous matter contained in all seeds, and some roots, as potatoes, &c. It seems to have been intended for the nourishment of the young germ or plant; but it has become, especially that of wheat, the favorite food of a great part of mankind. Fecula is compounded of starch, gluten, mucilage, and a little saccharine matter, but of these, starch is the most abundant.

Starch. If a quantity of wheat flour is tied in a linen bag, and suspended under a dropping of water, the starch will separate with the water and leave the gluten behind. It may also be obtained by steeping bran in water. But the starch of commerce is manufactured by steeping good wheat in cold water till it is soft, when the starch in the form of a milky juice is squeezed out. When this juice is permitted to stand, the starch falls to the bottom, and the glutinous matter remains suspended in the water and undergoes the alcoholic and acetic fermentations; when poured off, it is found to contain phosphate of lime and ammonia. The starch is afterwards dried at a moderate heat, when it splits into small columnar masses of considerable regularity: it is composed of 43·35 car. 6·77 hy. 49·68 oxygen.

5. *Gluten*, is obtained from most vegetable substances, though it has not been detected in the potato. It is of a sticky, ropy, elastic nature, somewhat resembling gum; though unlike that substance, it is insoluble in water. Owing to the phosphate of lime contained in this substance, wheat flour makes better bread than any other. It also contains nitrogen and sulphur, and apparently bears a near analogy to the animal substance *gelatine*; in fact, as taken in different plants, it seems to graduate into that substance. In this latter sense it has been called the vegeto-animal principle. It is supposed to constitute the most nutritious part of the plant, to be what chiefly promotes fermentation,—and it is the principal constituent of yeast.

6 *Fixed oils.* Such oils are said to be fixed as will not evaporate by heat without being decomposed. They are contained in the seeds and kernels of plants; except olive oil, which is produced in the pericarp. Oil, with fecula, and mucilage composes the white substance of all seeds and kernels; and in it is contained the embryo plant, which it supplies with aliment, till the root strikes into the soil. Olive oil is composed of 79 carbon and 21 hydrogen. The fixed oils will not enter

into combustion till they obtain a temperature of 800 degrees; yet, they will absorb oxygen at all temperatures, when they become rancid by the formation of sebacic acid. Most vegetable oils contain mucilage, and animal oils always contain gelatine; but as mucilage is much more combustible than gelatine, which contains nitrogen, so vegetable oils burn more brightly than animal. However both may be purified by boiling them with tannin, and the most rancid may be cleansed by charcoal.

Some oils, as linseed, poppy, and nut oil, by the absorption of oxygen, are changed into a kind of wax; and they are therefore called *drying oils*, and are used in painting. The red oxide of lead is boiled in linseed oil to hasten the process, when the metal is precipitated and the oxygen combines with the oil. This kind of oil exudes from some plants, and forms a waxy concretion on the outside; but some of the fixed oils, during the oxydation, are converted into carbonic acid and water.

7. *Volatile oils* are the basis of all vegetable perfumes. They are called volatile, because they exhale at the usual atmospheric temperature;—this property is supposed to be owing to their great affinity for caloric. The odour of all plants or flowers proceeds from their volatile oil. It is seldom or never found in the seed, at least in that part which contains the embryo plant; but is often abundant in the rinds of fruits, especially the orange and lemon. In some plants it is chiefly in the leaves, as in mint, geranium, and all the sweet smelling herbs. In others it is generally distributed throughout all parts of the plant, whether root, stem, or seed, as in onions and garlic. In the sandal tree it exists in the wood; from some trees it exudes along with the sap and other ingredients, that form camphor, resins, myrrh, and asafœtida.—Volatile oils are generally obtained by steeping the herbs in water, and then distilling that water; those used for perfumes are frequently distilled along with alcohol, as lavender water,

All insects have a great dislike to vegetable perfumes or aromatic herbs, which are therefore used in museums to preserve the stuffed birds and other animals from their depredations, and no doubt plants are preserved while growing by their *aroma*. The leaves of fruit trees are sometimes all consumed, while the aromatic blossoms remain untouched. Travellers, whose sleep is molested by certain troublesome insects, would find protec-

tion in a night-dress, slightly perfumed with lavender or any odoriferous vegetable most agreeable to themselves.

8. *Camphor* is a very aromatic substance, obtained principally from the stem and roots of the camphor tree, a species of laurel which grows in China. and other eastern countries. But small quantities have been distilled from thyme, sage and other aromatic herbs; and it is often found deposited in volatile oil, after long standing: by some it is considered a volatile oil in a concrete state. It is very volatile and inflammable, insoluble in water, but readily dissolves in oil.

9. *Resins* are generally the exudations from trees. The most common are pitch, tar, and turpentine, which exude from the pine and fir. Copal, mastic, and frankincense are also among the resins. They are the produce of trees in warm climates, and seem to be formed by volatile oil operated on by oxygen. For when they are made by art, volatile oil and oxygen are blended together, and the products are resin, water, and carbonic acid. Their chief use is in varnishes. Being dissolved in oil or alcohol, which hardens or evaporates as soon as laid on, the resin remains as a coat of varnish.

Wax differs from resin in its being formed from the fixed oil of the plant, while the resin is from the volatile, it is composed of 82 carbon, 18 hydrogen, and a little oxygen.

10. *Gum-resins* are a combination of gum and mucilage,—myrrh and asafœtida are of this description.

11. *Balsam* is another variation of volatile oil. It consists of a mixture of resinous juices and Benzoic acid; and is supposed to be volatile oil converted into these during its oxydation.

13. *Gum elastic*, Caoutchouc or Indian Rubber. This is a white, milky, gelatinous fluid, which is obtained from two or three species of trees in the East Indies and South America, by making incisions in the bark. In this juice, collected in vessels as it stills from the tree, are dipped pieces of dried clay, shaped like those Indian-rubber bottles that we buy. A coat is thus formed on the outside of the mould, which acquires consistency and colour as it dries. These dippings are repeated till the coat is of a proper thickness, when the clay is broken and shaken out. The natives of these countries frequently make boots and shoes of it, having clay models for their legs and feet—they are said to be remarkably pleasant and easy, waterproof, and very durable.

13. *Extractive matter,* though a general term, is almost exclusively applied to the colouring matter of plants. Vegetable colours are less durable than mineral, which are oxygen and a metallic base, while the bases of the vegetable are carbon and hydrogen. On being exposed to the air, the oxygen enters into a closer combination with the hydrogen which is consequently detached, when the carbon presents a different colour. A great many of the colours used in dying arc vegetable, among which are the *lakes.* Indigo is extracted from the plant *Indigofera Tinctura* grown in Mexico and the East Indies, as also from Woad. It is supposed to contain a little nitrogen, and may be obtained in white crystals, that become blue on exposure to the air by imbibing oxygen.

The art of *Dying* altogether depends upon chemical affinities. Therefore should the colouring matter and the substance to be dyed consist of the same elements, they will not unite, or in common language that substance will not take the colour. Hence linen and cotton cannot be dyed with vegetable colours. In such cases another substance is introduced that has a strong affinity for both the colouring matter and the material to be died; and not only must it make the linen and cotton take the colour, but also cause them to retain it, in washing and all other processes to which they may be exposed. This third substance is called the *mordant.* Alum is generally used, but sometimes the alkalies, and sometimes the oxide of tin or iron. Animal substances as silk, fur, and wool, will receive a vegetable colour, owing to the nitrogen, lime &c. which enter into their composition, so that they may be said to contain a natural mordant.

14. *Tannin* is a vegetable substance, forming the astringent principle inherent in a great variety of plants, and other vegetable productions, as nut-galls, the rose-tree, and port wine; but it principally exists in the bark, and especially that of oak. The following table was calculated by Sir. H. Davy, and contains the quantity extracted from 480lbs. of bark of middle sized trees, taken in the spring when the quantity is greatest.

	lbs.		lbs.		lbs.
Oak .	29	Ash .	16	Black Thorn .	16
Spanish Chesnut	21	Beech .	10	Coppice Oak .	32
Leicester Willow		Horse Chesnut	9	Inner rind of Oak	
large .	33	Sycamore .	11	Bark .	72
Elm .	13	Lombardy Poplar	15	Oak cut in Autumn	21
Common Willow		Birch .	8		
large .	11	Hazel .	14		

These substances impart it to water, whence it may be precipitated by isinglass or gelatine, with which it strongly unites and forms an insoluble compound. From its very great affinity for gelatine, it is of the utmost service in the art of tanning. Skins principally consist of gelatine, and being a long time steeped in water containing tannin, or bark ground or chopped very small, acquire weight, thickness, rigidity, and impermeability to water, by reason of the union of the gelatine and tannin. The process may be accelerated by dipping the skins in a concentrated preparation of tannin previously separated from the bark, but the leather thus prepared is of an inferior quality. Tannin has been imitated or made by exposing carbon to the action of nitric acid. The effete bark, after the tanner is done with it, is used for procuring heat in the garden hot-houses;—it is merely piled in a heap, when its decomposition evolves caloric.

15. *Woody Fibre* is that part of plants or trees which gives shape, strength, and consistency to the whole. Though it is the solid superstructure yet it is so porous that when examined with a microscope, the most dense and compact exhibits more space in pores than in solid fibre. If a piece of wood be cemented into the orifice of a receiver, the outer end having a hollow like a cup scooped in it, wherein is placed a little quicksilver, while the receiver is exhausting, the mercury will be forced with a stream through the pores of the wood. In the living plant, these pores are the channels and residence of all the fluid and evaporable parts, which when dispersed leave the woody fibre as charcoal.

16. *The Vegetable acids* are about 12 in number, their elementary substances are carbon, and hydrogen, saturated with a varying quantity of oxygen, which alone determines the character. Some exist in a natural state in the plant, yet none of them are uncombined, being generally found as salts in which the acid predominates; and the rest are procured by art. Their

names are as follows: acetic, oxalic, tartaric, citric, malic, lactic, gallic, mucous, benzoic, succinic, camphoric, and suberic acid.

Acetic acid or vinegar is principally obtained from liquors that have undergone the vinous fermentation. But it may be extracted, though in an impure state, from wood; and it exudes from the pores of the skin along with nitrogen and other perspirable matter. Though all kinds of wine, or fermented liquors will yield it, yet the more mucilage they contain, the sooner they will acidify. On this account isinglass should not be added to wines to fine them till the moment they are bottled. This acid cannot be concentrated by evaporation, being nearly as volatile as water; but on this account it is capable of being distilled as a colourless fluid; and, in short, it is the only vegetable acid that can be distilled in combination with water. The only way to separate it from water, is, to mix them with powdered charcoal, which being submitted to a boiling heat, the water is evaporated, but the acid is retained by the charcoal, whence it is afterwards dispelled by a stronger heat in a proper apparatus. Concentrated acetic acid is obtained by decomposing some of its salts, as acetate of copper, acetate of potas and soda, with sulphuric acid, and then distilling the products. The acid thus obtained is inflammable, very pungent, acrid, corrodes animal substances; and so volatile that it entirely evaporates when exposed to the air,—hence it has been supposed to contain ether. It dissolves camphor, and when mixed with volatile oils forms aromatic vinegar.

Oxalic acid. This acid is the highest degree of acidification, next to carbonic acid, that is known of. Acetic acid by the addition of oxygen becomes oxalic acid, and another dose converts it into carbonic acid and water. It is found principally in the juice of sorrel, combined with potas; but its basis abounds in many other plants and vegetable substances, as in the chick-pea, and particularly in sugar,—hence it is sometimes called the acid of sugar. It crystallizes in four sided prisms, has a very acid taste, and is insoluble in water. It is composed of 70·689 oxygen, 26·566 carbon, and 2·745 hydrogen. Its water of crystallization is 23 per cent. It is chiefly used by the calico printers.

Oxalic acid has a greater affinity for lime than any other acid, with which it forms an insoluble compound, hence it is the best test for that earth. But sometimes when it is supersatu-

rated with potas, it is necessary to take up the excess with caustic ammonia before this test is used. *Super-oxalate* of potas is sometimes made by art, but is the true juice of the sorrel. This acid attacks iron, zinc, tin, antimony and lead; dissolves all the metallic oxides, and forms with them triple salts. From its great affinity for iron, it is used to take iron moulds and inkstains from linen. *Sal-acetosellæ*, or the salt of sorrel, is imported from Switzerland, and the neighbouring countries, where the sorrel is cultivated for the purpose:—100 lbs. of the plant is said to yield 5 oz. of crystallized salt. *Oxalate of lime* is one of the compounds frequently found in human calculi. Crystallized oxalic acid very much resembles Epsom salts; perhaps the best mode of distinguishing them is by the taste:—the Epsom salts have a bitter, saline, and nauseous taste, while that of the acid is decisively, and excessively sour. Calcined magnesia is its best antidote.

Tartaric acid is obtained from the tartar of commerce, and is chiefly used by the calico printers to discharge false prints. It may be crystallized, is very soluable in water, and is composed of 69·321 oxygen 24·050 carbon, and 6·629 hydrogen. Its water of crystallization is 11¼ per cent.

Tartar or *Argol* is procured from vessels in which wine has been kept; during the process of making wine it is carefully collected, and becomes a considerable article of commerce in the wine countries. It is what forms the crust on the bottles of Old Port; and when purified from the tannin and colouring matter, is called *Cream* of Tartar. In both cases it generally consists of 77 tartaric acid, and 23 potas, and is therefore a supertartrate of potas. When this excess of acid is saturated with soda, the compound is called *Rochelle* Salts, which are composed of 54 tartrate of potas, and 46 tartrate of soda.

Citric acid is found in the juice of lemons and several other fruits. It crystallizes in beautiful rhomboidal prisms, and is entirely acid to the taste. Its composition is 54·83 ox. 41·37 car. and 3·80 hy. The perfect crystals contain 21 per cent. of water. This acid is used in a number of domestic purposes, in medicine, and in the arts especially by the calico printers. It is said that a very large dose of opium may be taken with a proper quantity of this acid, which instead of causing stupefaction, induces cheerfulness succeeded by gentle and refreshing sleep. Citrate of potas is chiefly used for what is called the *saline draught*,—it consists of 56 acid and 54 potas.

Malic Acid is obtained from the juice of apples, strawberries, and other summer fruits, in all which it exists ready formed. It may be crystallized. Its chief use is as a chemical test, and principally in separating alumina from magnesia,—composing with the former an insoluble salt, and leaving malate of magnesia in solution. It will precipitate mercury, silver and some other metals, from their solutions in nitric acid, and gold from its solution in aqua-regia.

Lactic Acid might perhaps be more properly classed among the animal acids, since it is obtained from milk, but it consists only of carbon, hydrogen, and oxygen, while they contain nitrogen. It is extracted from whey, is of a yellow colour, incapable of crystallization, and of no use.

Gallic Acid is procured from nut-galls, and is always combined with tannin. It gives a black colour to the solutions of iron; hence the use of nut-galls in making ink. It exists in the excrescences found on the roots of young oaks; also in the leaves, bark, and wood; and therefore the chips or saw-dust of these have often been used in dying black. It may be obtained in thin transparent plates, and in very small needle-shaped crystals;—its taste is peculiarly austere and very acid. The *nut-galls* of commerce, so extensively used in dying black, are the excrescences on the bark of young oaks, grown in warm climates, especially in Asia Minor. They are caused by an insect making a hole in the bark to deposit its egg. The vessels being lacerated occasions an exudation of the sap round the place. When the animal is hatched, it feeds upon, and eats its way through the side of the nut and escapes:—hence they have a hole in the side, or if not, the insect may be found in them.

Mucous or saccolactic acid is obtained by nitric acid from gum Arabic, and other mucilaginous substances. It is a white, gritty, slightly acid powder.

Benzoic Acid, or Flowers of Benjamin, is chiefly procured from the balsam called Benzoin, which is an extract from a tree that grows in Sumatra, and another in Peru; also from liquid storax. It has likewise been discovered in the urine of children, and graniverous animals, as well as in blood, and in some fungous productions. The best Flowers of Benjamin is a brilliant white powder, unalterable in the air, soluble in alcohol, and in boiling water, but not in cold water, and may be totally evaporated by heat. Its taste is acid and bitter; and it has a

peculiar aromatic odour. It is composed of 74·41 car., 20·43 ox., and 5·16 hy.

Succinic Acid is obtained from amber. It is slightly acid to the taste, soluble in hot water, but very sparingly so in cold; sublimes at a very high temperature, and crystallizes in white, shining crystals. Combined with ammonia, it forms a valuable test for separating iron from its solutions without affecting other metals. One hundred grains of such precipitate contains 68 of iron.

Amber, (see page 474) supposed to be a vegetable resinous substance acted on by sulphuric acid, is found upon the sea shore, also in a species of whale, and therefore has been supposed to have had an animal origin. It is transparent, combustible, and readily manifests electricity. In short, electricity was first discovered in this substance, whose latin name is *electrum:* hence *electricity.* It was greatly esteemed by the ancients, and worn by the ladies as an ornament of dress.

Camphoric Acid is procured by means of nitric acid from camphor. It has a bitter taste, only slightly acid, smells like saffron, and forms very white crystals. Any quantity will dissolve in boiling alcohol; it is also very soluble in boiling water, but requires a hundred times its weight of cold water to dissolve it.

Suberic Acid is obtained by means of nitric acid from cork. It may in like manner be obtained from paper. It is generally in a pulverized state; cannot be crystallized; and has not been applied to any use.

Tea. That part of tea on which its value depends, is found to consist of tannin, gallic acid, and extractive matter. The following results were obtained from teas of the undermentioned prices.

Black Tea	12*s*. per lb.	35 per cent.		Green Tea	14*s*. per lb.	41 per cent.	
-	10*s*. .	34	-	-	12*s*. .	34	-
-	8*s*. .	37	-	-	10*s*. .	36	-
-	7*s*. .	36	-	-	7*s*. .	31	-
-	6*s*. .	35	-				

The above portions were extracted by frequent infusions of boiling water, after which another portion was obtained by alcohol, of a resinous nature. That from the highest priced

black was 12, from the lowest priced 6; from the green it was 10. There is nothing in the composition of *Green Tea* different from the black; so that there seems to be no foundation for the supposition that it is less wholesome. If there is any thing it must be a volatile oil, which may be evaporated by a few minutes boiling; but the genuine tea-drinker would consider this the best part of it.

The *Bitter* and *Narcotic* principles have been extracted from vegetables, but their composition is not ascertained. The former is in deep yellow crystals, is supposed to contain a little nitrogen, and has the property of stopping fermentation. The latter, *Narcotin*, or *Morphin*, is in rectangular prisms, with rhomboidal bases, and is destitute of taste and smell. Besides the above, there are many other vegetable substances mentioned by writers on chemistry, which it would be tedious to particularize.

3. FERMENTATION.

When plants cease to be elaborated by life, which in the course of nature is generally after they have bloomed, and yielded fruit or seed, a new arrangement of their materials begins to take place, occasioned by mere chemical attraction. This is a mere extension of the Almighty Fiat, "Dust thou art and unto dust thou shalt return." For, were they not thus resolved into their original elements, they would encumber the surface of the earth so much as to impede vegetation. But in the progress of this dissolution their materials form several new arrangements. While the combinations are going on, or the particles are torn from the old arrangements; a violent internal commotion, occasioned by the liberation of caloric and carbonic acid gas, is observed to take place in the liquor. This motion or process is called *fermentation*.

There are generally reckoned four fermentations, or different arrangements which the elements make, before they arrive at their ultimatum, viz. the *saccharine* or that wherein sugar is developed or formed; the *vinous* or that which produces alcohol; the *acetous*, or that of acetic acid; and the *putrefactive*, or that by which water and carbonic acid are formed. At the end of each process, a cessation of the fermenting operation takes place, and for a while the liquor remains at rest. Unless therefore the products are secured, the next fermentation suc-

ceeds; and the elements carbon, hydrogen, and oxygen make a still closer union, evolving heat every time till the putrefactive process is completed. Yet all vegetable productions, will not undergo these fermentations; and many circumstances are required to render each process complete in any of them. The chief requisites are a certain degree of heat, a sufficient quantity of water as a solvent, and a treatment peculiar to each fermentation.

The Saccharine Fermentation. Though sugar is formed by nature in most plants while growing, and in some fruits while ripening; yet before it is developed in other vegetable productions, a new elementary arrangement takes place after their decease. In certain roots as carrots and parsnips, it is developed during the process of cooking; also in potatoes, but much more so if they have been previously submitted to a slight frost. In some grain it is produced during the germinating process;—the seed is deposited in the earth, whence it absorbs moisture which makes it swell;—a chemical combination, in the mean time, taking place produces a certain degree of temperature; the seed bursts, the young germ appears, and the rest of the farinaceous matter is converted into a milky pulp containing a great deal of saccharine matter. At the formation of the seed in the parent plant, there is also a considerable quantity of this substance; in flowers, it is in the germ which afterwards swells into the pericarp. The ripening of fruit seems to depend upon absorbing oxygen, hence if some fruits are gathered a few days before they are quite ripe, and be totally excluded from the air, they will be preserved. But as they were not ripe when pulled, they should be withdrawn a few days before they are used, when they will absorb oxygen and be in fine perfection.

The saccharine fermentation is artificially produced in the process of making malt. The grain, generally barley, is steeped for two or three days in water; when, the water being withdrawn, the fermentation commences, which is manifested by the grain swelling, bursting and germinating. In the mean time a considerable degree of heat is evolved, which, as the grain is laid in a heap, hastens the process. When the sprouts are about an inch in length, the process is suddenly stopped by placing the grain upon a kiln, where it is well dried at a gentle heat. It is thus rendered crisp and friable, and capable of being preserved till such time as it is submitted to

The Vinous Fermentation. In order to promote this fermentation it is necessary to bruise or grind the malt, and to macerate the other materials, lest the divellent power should not be sufficient to overcome the cortical or woody fibres; there must be a sufficient quantity of water as a solvent; and yeast, or some other ingredient which is undergoing or has undergone this fermentation, must be added: and the whole raised to a temperature of about 55 or 60 degrees. The products of this fermentation are alcohol, and carbonic acid; the latter of which is evolved in vast quantities during the process. The alcohol remains in the liquor, forming in it the intoxicating quality, for it is to this substance that all inebriating drinks owe their peculiar property; and here is the foundation of the various operations of making wine, ale, beer, and of the process of distillation.

Wine. In making wine the juice of the grape in which the sugar is already formed, is merely put into large vessels, when the vinous fermentation succeeds;—the temperature of the climate and the acid contained in the tartar commencing the process. It is found that where all the tartar has been withdrawn from the *must*, fermentation will not take place, and as the juice of the grape contains a large portion of water, there is no occasion to add any. When the fermentation ceases, the liquor cools, and subsides becoming clear and transparent, and possessing the spirituous qualities. If it is put into the vessel and closed up during the fermentation, then it retains some of the carbonic acid, and when brought forth sparkles in the glass. In making British Wines, it is necessary to add a great quantity of sugar, which yields more alcohol than any other substance: but the nice point to be observed is to put the wine into a strong cask, and close it before the fermentation ceases. By doing so, some of the sugar remains undecomposed, which imparts sweetness, and the carbonic acid gives it life, that makes it clear, bright, and sparkling in the glass; and at the same time imparts a brisk acidulous taste, which corrects the flatness often predominant in these kinds of wine.

Ale or Beer. The process of making beer differs little from that of wine; and therefore, it may properly enough be called the wine of barley. But another ingredient besides the yeast necessary to commence the fermentation, is added, viz. hops, which restrain or regulate the fermenting process: a large quantity stops it altogether. Without hops the beer could not

be preserved, from passing into the acetous fermentation, and being converted into vinegar. But the common brewer in some measure performs the same office by his strong hooped casks.

The Acetic Fermentation. When a liquor has undergone the vinous fermentation, if its products are not secured from the contact of the air, its carbon and hydrogen, not having their complement of oxygen, soon begin to take another dose from the atmosphere, with which they combine more closely, evolving caloric and producing acetic acid. The fermentation of paste or dough, for the purpose of making bread, is generally considered as the commencement of the acetous; though some suppose it to be a distinct process, and have called it the *panary* fermentation.

The Putrefactive Fermentation. This is the last step of nature towards reducing organized bodies to their simplest combinations. All vegetables, providing there be heat, moisture, and free access of air, spontaneously undergo this final decomposition. When all these are in sufficient quantity, then the dissolution is the most complete: carbonic acid and water being the ultimate arrangement of carbon, hydrogen, and oxygen. But several circumstances tend to check or prevent this fermentation. As when a proper solvent, such as moisture is wanting; for it is well known that plants and wood, if well dried, will resist the attack of the air for any length of time, and even when there is not a sufficient temperature. In general 55 degrees are necessary for a perfect fermentation, but no fermentation was ever known to occur at a temperature below the freezing point. Sometimes vegetable substances have both heat and moisture, but are secluded from the air, so that a supply of oxygen cannot be had. In this case fermentation to a certain degree goes on; that is, a new arrangement takes place so as to destroy the vegetable fibre, and make a closer union among the particles, without their being oxided, so that they retain all their inflammability. To this kind of fermentation we perhaps owe a great many bituminous substances.

4. DISTILLATION.

WHEN a liquor has undergone the vinous or alcoholic fermentation, instead of its being preserved as wine or beer, it is sometimes made to undergo the process of *distillation*, which

is merely separating the alcohol from the water and other ingredients. However, for distillation, the process of fermentation, though the same in principle, differs widely from that of wine, or beer. For these, the fermentation is very gentle, or is checked to prevent the formation of acetic acid; while for distillation, it is urged to the utmost degree. For this purpose more yeast is added, and the rise of temperature, which for beer does not exceed 15 degrees, will sometimes be more than 50. For beer, malt alone is used; but for distillation a small portion of malt, varying from one-third to one-tenth is mixed with raw materials; they are ground together, and yield a wort nearly as sweet as that from an equal quantity of malt alone.

Retorts or *Stills* are of various sizes, from the small glass one that holds less than half a pint, to that of the large distilleries, containing many gallons. The top is steam tight, large, and partly of a bulbous shape, which terminates in a pipe called the *worm*, that conducts the spirits into the receiver. The worm is generally of a spiral shape, passing through a vessel of cold water, so that the vapour is condensed before it enters the receiver. The necessary heat is below that of boiling and a great deal depends upon its regularity. The principal on which distillation is effected, is this, viz. alcohol, is more volatile than water, and when submitted to a heat a little below boiling, rises in vapour, and leaves the water and other ingedients behind, or escapes with the first steam after boiling commences.

Brandy is distilled from wine. It is alcohol mixed with a considerable quantity of water, and some of the undissolved particles of the grape, which determine its peculiar flavour. When distilled, it is perfectly clear, leaving the tartar and colouring matter behind, precipitated to the bottom of the retort; and it afterwards obtains its colour by being put into new casks, whence it extracts the tannin, gallic acid, and extractive matter, which give it the dark and deep tint. If this is not sufficient, it is increased by the addition of burnt sugar or molasses. The average quantity of alcohol, found in Port wines, is from 19 to 25 per cent. Some of the white wines afford more, some less; but in general, only such wines are distilled as will not sell as wine. Gooseberry wine contains only about 11 or 12 per cent. of brandy.

Rum is obtained from sugar, or molasses. After the canes are bruised between the iron rollers, and the principal part of

the juice is pressed out, they are thrown into water, which extracts the rest. This liquor is separated, fermented, and afterwards distilled, when *rum* is the produce. It is perfectly clear, and receives the colour in the same manner as brandy. 100 lbs. of sugar and 10 of yeast will yield 57·7 lbs. of alcohol, and 35·34 carbonic acid, and a residuum of 6·59 lbs.

Gin is obtained from malt, a pound of which, when fermented and distilled in the most complete manner, will yield half a pound of alcohol of the specific gravity of ·825. In common processes, after the wash has undergone the vinous fermentation, it is separated from the grains and put into the still. The process is thrice repeated for the British Gin; the first two times by the common *Distillers*, when it is called *raw-spirit*. From them it goes to the *Rectifiers*, whose trade is distinct from that of the distillers. For the *common gin* 18 gallons of raw spirit, and 2 of spirits of turpentine are distilled together; to which a smatch is given with the juice of the juniper-berry, a fruit principally brought from Italy; sometimes the last distillation is performed with the juniper in it. In Holland it is but twice distilled. Near two-thirds of wheat flour are used with the malt, and the whole for the first process is put into the still. *Whisky* is also only twice distilled, and without any ingredient to improve its taste, except the smoke it catches in the process. It is obtained not only from barley, oats, and rye, or whatever grain is the cheapest, but also from several other vegetable substances, wherein the saccharine and vinous fermentations can be excited. Potatoes are said to afford a brandy inferior in flavour to none of the French brandies.

The fiery taste found in bad spirit is caused by the presence of an empyreumatic oil, chiefly formed by having an irregular, or too hot a fire, by stirring it or throwing on coals during the process. On such occasions this oil, or *roughs* as it is called, flies off into the receiver. But a great many different ingredients and processes are used for the rectifying this bad taste, or the separation of the oil, on which the quality of this inferior kind of spirit depends.

Arak is distilled from rice; and the Arabs have a spirituous liquor called *Koumis*, which they obtain from fermented mare's milk.

Alcohol or Spirits of Wine. Though alcohol is the basis and strength of all the above spirituous liquors; yet in all of them it is combined with a considerable quantity of water, and impreg-

nated with some vegetable particles, which give to each its peculiar flavour. Gin, rum, and brandy contain, on an average, about half their quantity of pure alcohol, and ale is supposed to average from 6 to 10 per cent. In order to obtain pure alcohol, it is necessary to distil or rectify it several times over, mixing it with different ingedients that assist in separating its aqueous and vegetable particles; when at last it is of the same quality, whatever it is procured from, whether grapes, barley or potatoes. The strongest alcohol or spirits of wine of commerce is seldom of a less s ecfic gravity than ·825, what is called proof spirit is ·930. The exact proportions of its elements have not been satisfactorily determined; but a French chemist demonstrated that alcohol of ·792 specific gravity, contained 51·98 carbon, 34·32 oxygen, and 13·70 hydrogen.

Alcohol, besides its being the inebriating quality in wine, ale, cyder, and all spirituous liquors, forms the bases of all cordials, liqueurs, elixirs, tinctures, quintessences, &c. For cordials and liqueurs, it is sweetened with sirup and flavoured with volatile oil; and for the others, it has resins and balsams dissolved in it, being reduced with water. It is also of the greatest use in chemistry, being a solvent for a great many substances, which cannot be dissolved by water and heat. It is highly combustible, will inflame at a low temperature, and burn without a wick. When its vapour is made to pass through a pipe, and come in contact with the flame of a lamp, a kind of blow-pipe is formed which produces a very intense heat.

Ether, the lightest and most inflammable of all fluids, is obtained from alcohol, of which it forms the more volatile part. It is separated by mixing a quantity of alcohol in a retort, with a portion of sulphuric, nitric, or muriatic acid, when the acid extracts some of the oxygen from the alcohol, rendering the remaining elements less intimately combined; so that a new substance is produced, which flies off in vapour and is collected in a proper receiver. The specific gravity of good *sulphuric ether* is about ·750; and its composition nearly 67·98 carbon, 17·62 oxygen, and 14·40 hydrogen. As a medicine, ether is the most effective antispasmodic known. It has the same intoxicating quality as alcohol; and when used in excess, produces the same pernicious effects.

CHAP. XVIII

Vegetable Economy.

1. Analysis of Soils. 2. Agricultural Character of the English Soils. 3. The Food of Plants. 4. Germination, 5. Organization. 6. Fructification. 7. Vegetable Chemistry. 8. Vegetable Heat.

1. ANALYSIS OF SOILS.

Having described the elementary parts of vegetables, the compound substances formed in the living plants, and the products of fermentation or decomposition; it will be almost needless to say that their dissolving materials mix with the earths to form soils, and re-enter a fresh succession of plants, which also in process of time decay; and thus a circulation of vegetable matter is continually going on. *Soil* or mould, then, is that thin coat, which in gardens and other fertile places, forms the surface of the earth. Part of it consists of manures or vegetable and animal substances undergoing the putrefactive fermentation; but the basis of all soils is silica, with alumina, lime, magnesia, and the oxides, alkalies, and salts that we have already enumerated as entering occasionally into the composition of rocks. Yet the above earths form rather the matrix for the root of the plant than the pabulum; the true food being, as is proved by experiments, carbonic acid and water; the former they can procure from the atmospheric air, though not in sufficient quantity for luxuriant vegetation, but on a due supply of the latter, viz. that there should neither be too little or too much, their growth principally depends; and the efficacy of

the above four earths in the process of vegetation consists in their contributing to this regular supply of water to the roots of the plant.

Silica is the earth that enters the most abundantly into the composition of all soils; and it may be laid down as a general rule, that no soil can be fertile whose basis does not contain a full half of this earth. A fertile soil near Bristol was found to consist of the following ingredients: 60 silica, 12 alumina, 7·5 lime, 3·5 oxide of iron, 1·25 vegetable fibre, ·75 vegetable extract, ·5 magnesia, 13 water, 1·5 loss,=100. However it may be laid down as another general rule, that silica requires from one-third to one-fifth or sixth of alumina to produce fertility. Sand alone permits all the water that the clouds precipitate upon it to glide downwards to a depth far beyond the source of evaporation, and consequently to the vegetable kingdom it is entirely lost; the soil on the surface is therefore immediately dried by the sun, and the plants languish and die for lack of moisture. Such soil is also liable to be dispersed by the wind, and the thin turf is occasionally torn off in rolls.

Alumina, next to silica, is the earth that enters the most abundantly into the composition of fertile soils, and is what gives them the *tenacious* character. This earth has great affinity for water, and rapidly imbibes a large quantity, so that it soon becomes saturated, and then swells in the mass to such a degree, that its density is too great for the water to penetrate; hence alumina and consequently clay are impervious to water. Therefore, when rain falls in torrents, as is frequently the case in summer when it is the most needed, upon soils containing too much alumina, it is precipitated into the ditches; or, if more slowly, as in winter, it is retained too much upon the surface, and consequently among the roots of vegetables, which are thus in danger of perishing by the solvent power of the superabundant moisture overcoming the unctuous coat and cohesive power of the seed or plant; or, by the cold occasioned by the water dissipating too much of the vegetable heat: for vegetables as well as animals have a temperature, that in winter is greater than that of the medium in which they are placed. But as the most tenacious soils contain a full half of silica, the silica renders the soil pervious to water, so that the water penetrates to the subsoil. But in doing so, the alumina imbibes and retains a large quantity, and thus the soil is cold, and very adhesive. Such soils therefore swell very much in wet weather, and, on the contrary, in droughty weather, when the moisture is evapo-

rated, they shrink in the same degree: hence in clayey districts the earth rends into columnar forms, not much unlike the columns of trap rocks; and it is not uncommon to see rents of this kind of above a yard in depth, and some inches in width. Such soils therefore cannot be the most productive, and they are also the worst to improve, since they are so adhesive, that after rains they always agglutinate into a tough unmanageable mass.

Lime. It is found by analysis that no soil is productive, which does not contain a considerable portion of lime. Specimens of fine black vegetable mould have been taken from fertile plots of land, where it was reasonable to suppose, that lime had never been deposited by the hand of man, still it was found that the fertility was chiefly owing to the presence of lime; so that wherever we see land in an uncultivated state, yet fertile, there we may be sure that nature with a liberal hand has deposited lime. This earth generally exists in soils in a carbonized state, that is as chalk or limestone, both of which contain about half their weight of solidified carbonic acid. Having this great affinity for carbonic acid, it is reasonable to suppose that it attracts more than the definite proportion from the atmosphere or manure of the soil, and thus retains it in the soil among the roots of the plants. And as it also has a great affinity for water, and enters the most largely of all the earths into the composition of plants, so by its decomposition this hydro-carbonate of lime must afford a constant pabulum.

The chalk formation is nearly pure carbonate of lime, and where the soil contains the least admixture of other earths are tracts nearly as sterile as any other English formation presents; so that we here have an example of too much lime; all the rain that falls upon it permeates immediately to the bottom of the formation, where it is retained by the argillaceous beds of the chalk-marle. With respect, therefore, to holding water, it more nearly resembles silica than alumina. But as it has a greater affinity for silica than alumina has, it detaches the alumina from the silica, and corrects the too great tenacity of clayey soils. Hence lime not only gives a permeability for water, but leaves the alumina at liberty to retain it. And this permeability is equally useful both in wet weather and in very dry: in the former it permits the superabundant water to drain off to the subsoil, so as to quit the roots of the plant; and in the latter, it allows a supply from the subsoil to rise in evaporation, and consequently in its ascent to come in contact with

the roots as well as the leaves of plants whereby a certain portion of it is imbibed; and thus the plants have a supply after the alumina is exhausted. But as the lime only improves the permeability of the soil, it is evident that if the subsoil wants permeability, in wet weather the water will be so much retained by the subsoil that it must stand equal with the surface of the soil. Hence the subsoil should always be looked to, before the agriculturist is at any expense in improving the soil, otherwise he may possibly have all his useless attempts to place to the score of loss. Draining, which is very truly stiled "the *soul* of improvement" must be the first process, and where the subsoil is of such a nature as to render this comparatively impracticable which is very rarely the case, he should turn his attention to a more promising speculation.

In the improvement of soils with lime, two circumstances besides the above, should be attended to. When there is much vegetable matter in the land in an undissolved state, which is only the case in new-lands, or such as are of a mossy or peaty nature, the lime should be laid on in its caustic state, that is, as soon as it comes from the kiln, and immediately ploughed in; when it will dissolve the vegetable fibre, and absorb the superabundant carbonic acid. But if it be suffered to lie in a heap till it fall, and then be spread upon the land, and further exposed to the air, it will be saturated with carbonic acid from the atmosphere, and will as a solvent or absorbent do no good. However in this case, it should be early laid upon the fallows;—for if it is not sufficiently mixed with the soil, and fully saturated with acid previously to the sowing of the grain, it will destroy the germinating principle of the seed or young plant, and will sterilize instead of fructify the soil. On the contrary, in poor, old, or worn-out soils, a supply of carbonic acid is the ingredient chiefly needed; and, therefore, the lime should be spread upon the land, and exposed to the air a considerable time, in order that it may be fully saturated with the acid before it be ploughed in. Yet the farmer, who in this last case, looks forward to the first, or first few crops for a full remuneration of his labour and expense in lime dressing his fallow, may be disappointed. For the effect that lime has on worn-out lands is different from that of manure: the latter being spent in three or four years, while the former, to a certain degree, lasts for ever. For, notwithstanding lime enters into the composition of most grain, yet the quantity thus consumed is comparatively small.

However in soils that originally contain little or no lime, the quantity laid on is far below the specific quantity for a fertile soil:—this should not be less than one eighth of the earthy base of the soil; and calculating the depth of soil necessary for the range of the plough at from six to eight inches, it would amount to nearly two hundred tons of quick lime per acre. When poor land is improved to any great extent by liming, the landlord ought to pay for the lime, (the carting and labour, if it is at any considerable distance, being more than enough for the tenant,) since it is improving the land for ever; but then he may expect a corresponding advance of rent. The peculiarly great effect often produced in the first crop after lime dressing, may chiefly, in general, be attributed to its solvent properties; so that when the lime has been laid on too caustic, it may cause one good crop at the expence of succeeding crops.

Marles, on account of the carbonate of lime which they contain, are useful in agriculture; but only so when they contain 30 or 40 per cent. of this substance—if they contain less, they are not worth the labour. The easiest method of ascertaining this, is, by dissolving a little of the dry powdered marle in diluted muriatic acid. By this means the carbonic acid will be detached from the lime, and will escape; and the quantity of lime may be known from the weight which the whole has lost. It an ounce of marle lose 40 or 45 grains, its value, when compared with that of lime, is only as about 1 to 7.

Magnesia does not exist in the composition of the earth's shell, in a greater proportion perhaps than about one per cent., and in this proportion it seems to be favourable to vegetation. In France are extensive chalk districts rendered altogether sterile, by the presence of 11 per cent. of magnesia; and some of the tracts upon our magnesian limestone are among the most barren of the English soils. When a load of quicklime, from the magnesian limestone has laid for a few days upon the fallow, previously to its being spread, the spot is rendered sterile for some years afterwards; whereas, on the contrary, where a load of chalk-lime or of lime from the mountain limestone has been so placed, that spot will produce the most luxuriant crops. Magnesia does not enter into the composition of land plants, and it has less affinity for carbonic acid and water than lime has; but its most injurious effect on vegetation perhaps is owing to the tardiness with which it becomes saturated with carbonic acid: so that it seems to continue years in the soil

before it is rendered mild; and of course is all that time both pernicious to the root of the plant and exhausting to the soil, since when in the soil it must be imbibing the carbonic acid the true pabulum of the plant.

Soils are the pulverized remains of rocks, as we have stated in various places in the chapter on Geology; and therefore, along with the above four earths, which principally compose them, must be a great many other substances. Of these, perhaps oxide of iron is the most abundant; and as it enters into the composition of almost all plants, it must be a fertilizer of soils. Sulphate of iron often occurs, and is a great sterilizer, but lime decomposes it, and sulphate of lime and oxide of iron are the result, both valuable manures. Potas seems a necessary ingredient, as it enters into the composition of most vegetable substances; but is chiefly in the young leaves; the sear leaf seems destitute of it, so that wet weather perhaps deprives them of it. The other substances found in plants are either in too minute quantities in the soil to be detected; or, the plants extract them from the atmosphere.

The science of Geology is now so far advanced that an agriculturist may generally know, without analysis, the chief ingredients of his soil. Yet it is a duty, which every landowner owes to himself and the public, to have a geological *plan* of his estate; with the composition of the soil and subsoil, as well as the various strata, marked upon it. Let him not be led to do this by the delusive hope of finding valuable mines on his property, he will generally be rewarded by knowing its utmost value, the capabilities of improvement, and the nearest places, whether on his own land or on that of his neighbour, whence to obtain materials for the impovement of the soil.

2. AGRICULTURAL CHARACTER OF THE ENGLISH SOILS.

We have already stated, page 393, that if the elementary ingredients composing the earth's shell, were regularly blended in one mass, it would form the basis of the richest soil. With such a surface we suppose the earth to have been originally created; nor can we form an idea, that appears to us more consonant with the miracles recorded in the Old and New Testaments, than this, viz. that the *curse* pronounced upon the earth was effected by separating these ingredients from each other, and arranging them in masses, so as to render them comparatively

sterile from want of due mixture; and, at the same time, changing the earth's temperature, which in consequence, would cause some change in the constitution of the atmosphere. Nor can we help observing how wonderfully these separated materials are arranged by the side of each other. Just as if the Almighty had said, "Let us destroy this Garden of Eden, of which man is no longer worthy, by separating the ingredients of the soil; and instead of the mist of the earth that now waters the whole face of the ground, let us cause the atmosphere to be troubled with storms, and loaded with vapours, wherewith in future it shall be moistened. Nevertheless, that man may not perish, let us cause some parts to be so blended that he may at first easily procure food; and let us dispose the whole materials so, that when man shall multiply upon the face of the earth, he may be occupied in blending together what we shall now separate."

Agreeably to this hypothesis, we find tracts of sand, clay, and lime alternating with each other in regular succession; not only in England, but to a certain degree throughout the whole world. Nor can we suppose that England will have arrived at its utmost limits of agricultural improvement, till this blending of the materials is effected. Should we take a retrospective view of the state of this island two thousand years ago, when the inhabitants lived chiefly on herbs, milk and flesh, and mostly resided in turf hovels or wigwams like the natives of North America; and then trace the improvements in agriculture through the last thousand years; and farther state, that the soil of England is capable of improvement till every subsoil is completely drained, and till the ingredients of each formation are so distributed that the soil is blended in the most favourable manner; at the same time comparing the means of removing weighty materials, along rail-ways and by other means which science has yet in store, with the means possessed by our forefathers a thousand years ago,—our Eutopian scheme of all the less elevated parts of England being rendered as fertile as the most fruitful garden, at the end of one or two more decades of centuries, will not perhaps appear so very improbable.

The soils of England naturally divide themselves into three primary classes, viz. sandy, clayey, and calcareous, each including a number of secondaries, or subordinates.

The *sandy* are the outcrops of the siliceous formations; and the prevailing character of the most pure of them is *sterility*.

Commencing with the uppermost—the *Bagshot Sand*, claims our first attention. It is nearly pure silica, though occasionally mixed with brick earth, or clay without lime: it is therefore a very poor, hungry soil, producing only heath and furze, and presenting extensive wastes in the immediate neighbourhood of the Metropolis. The *Green Sand* that underlies the chalk marle is the next in order. It presents many downs covered with heath, both in Devonshire and Surry, but the valleys have often a light, loamy soil, especially in Wiltshire, of considerable fertility. A vast proportion also of the *Iron Sand* is covered with heath, as the Dissingham Heath, Norfolk. It is, in many cases, favourable to the growth of wood, as in the Wealds of Kent and Sussex; near Wobourn, Beds., are also extensive plantations upon it. However some parts of it are famed for fertility and early crops. In Cambridgeshire it forms excellent garden grounds, in Bedfordshire it is esteemed for the growth of potatoes, and some of the hop grounds of Kent are upon it. All the water which falls upon these sands permeate to the subjacent clays, and are generally thrown out as chalybeate springs, and occasionally as moving quicksands. The outcrop of the middle series of new-red-sandstone forms many sterile tracts, producing only fern, heath, bent, and a lean hungry grass. The sandy tracts of the coal-measures are of small extent, and are usually poor, and heathy. The millstone-grit generally forms elevated and barren moor lands, covered with mountain peat and mosses; to the growth of which it seems favourable, both from its cold and humid atmosphere caused by its elevation, and from its retentive nature, occasioned by its quartzose particles having an argillaceous cement. The most elevated parts of the old-red-sandstone are also covered with the mosses; but in lower situations, where it alternates with the argillaceous beds, and is farther capable of improvement from the lime of the superincumbent mountain-limestone, or the subjacent transition, it affords a luxuriant soil, as is proved by the rich fields and luxuriant orchards of Herefordshire.

The secondaries, or subordinates, belonging to this class, are the alluvial and diluvial formations; which in all countries are the most fertile and most highly cultivated tracts of land. Among these may be classed the conglomerate beds or gravel. They will include also the *Upper marine* or *Suffolk Crag*, which both in Suffolk and Norfolk affords a sandy soil, blended with

a rich loam, and constitutes the most fertile and highly cultivated tracts of England. The shelly mass of the Crag affords a useful manure for poor soils. The conglomerate beds of the new-red-sandstone, may be traced all the way from near Hartlepool to Nottingham, and afford many fertile patches, particularly famed for the growth of turnips and barley. But these beds are not always the most fertile, where they present themselves among the strata of the magnesian limestone.

The *clays* are the next class; the prevailing characteristic is a mediocrity of fertility, though their position is generally favourable from their low situation. The London clay first presents itself to our notice. It chokes the plough, and after rain adheres to the shoes, but is not slippery. It forms, in very dry weather, especially on the Nore, south of Walton, a sort of pavement, in some degree resembling the Giant's Causeway, being split into a number of small columns. It is favourable to the growth of wood, especially the oak, elm, and ash; but for corn, requires chalking. However in many places the strata alternate with sand; and where these are near the surface, there is a more kindly soil; and the greater part of its surface has alternate beds of rich marles, and loams, which often, especially around and beneath London, alternate with gravel and sand to the depth of 30 or 40 feet. The *Plastic clay* is composed of an indefinite number of sand, clay, and gravel beds, irregularly alternating; and therefore it presents many descriptions of soils, differing little from the kindred soils in other formations, but not the most fertile from a deficiency of lime. The *Weald clay* varies from a dark tenacious clay, to a blue-grey calcareous marle. It is favourable to the growth of wood; but from its deficiency of silica is not famed for fertility. *Kimmeridge clay* is favourable to the growth of oak. The soil of the *Oxford clay* is of three or four kinds. The most clayey is barren and unmanageable, yet the vale which extends from Melbury to Shaftesbury in Dorsetshire, is famous for butter; and in Lincolnshire, this formation is covered by a fertilizing chalk breccia, so that it appears like a white clay; and in many parts its agricultural character is improved by alluvial matter. A clayey soil predominates in the coal districts, being the outcrop of the slate-clay. It is poor, and requires a great deal of draining and liming; and when in pasture, is subject to be overrun with daisies and other insignificant weeds to the exclusion of useful herbage. The shale of the millstone grit is a

good deal of the same nature; though in some parts it contains lime, and is then more fertile:—sulphate of iron often prevails in these clays.

The *calcareous* soils. Of these the chalk forms the most prominent feature, and the prevailing characteristic of its most elevated parts is sterility; while that of its valleys is great fertility; but this chiefly where it comes in contact with other formations. In Champagne, France, it is, in places, absolutely uninhabitable, but there it contains magnesia; however, in England, the population is supposed to be less on the chalk than on any other secondary district, though the most barren parts generally afford pasturage for sheep. It is particularly favourable to the growth of the beech; the Chiltern hills in Oxfordshire were formerly covered with it, and afforded shelter to banditti; hence the office of the steward of the Chiltern hundreds, the acceptance of which, though now only nominal, enables a member to vacate his seat in parliament. The *oolites* are too numerous for us to particularize; lime, and silica are their prevailing ingredients, but these without clay do not form a fertile soil; however as they frequently contain beds of clay and fuller's earth, the valleys are often fertile. The cornbrash may be particularly mentioned for its fertility; and the fuller's earth of the inferior oolite, is very favourably compounded for the agriculturalist, and famed for its fertility; as is also, in a remarkable degree, the sand below this oolite. The soil of the *magnesian limestone* is very various, chiefly owing to its different strata or beds containing different proportions of magnesia—that earth varying from 11 to 45 per cent. It may be observed of most of its least fertile parts, that their prevailing character is a blue or red, dense, tenacious and cold clay; generally more favourable to tillage than pasturage from the growth of the pry-grass, or shar-grass *(festuca pinnata)* a short, sharp, bluish grass that nothing will eat. The more fertile parts present a chocolate brown soil, favourable to the growth of the spiked-heath broom grass, the sweet-scented violet, the yellow rose, and occasionally the oak, elm, and walnut trees. The *mountain limestone* is mostly too elevated to be fertile, and of too rubbly a nature for vegetation; but where the soil has been improved by burnt lime, it produces good pasturage.

Marles may be considered as subordinate to the calcareous class: they form some of our most fertile tracts of land. The *chalk marle* comprises three varieties of soil. The uppermost is

like the chalk; the lowest is too clayey and tenacious; the middle from a combination with both, presents a warm, crumbling, marly soil, very rich and valuable; and even the lowest beds, which graduate into the green sand, are occasionally greatly improved by flinty gravel and the debris of the overhanging chalk cliffs. There are some rich marly beds among the *oolites;* and the *red marle* of the new-red-sandstone, throughout its range, forms some of the richest lands in England, for nearly all kinds of grain as well as for pasturage; in some places it is equally famed for its cyder; though it contains some tracts deficient in lime, which are consequently cold and tenacious.

The transition and primary formations are generally too high for agriculture and of too compact a nature for pulverizing readily into soils. The slates or killas in Devonshire and Cornwall generally form a rubbly soil of shivery, not pulverized, fragments of slate. But the valleys containing diluvial and alluvial matter, and occasionally a considerable way up the southern side of the mountains, especially where there are siliceous and calcareous formations, from the quantity of fine vegetable particles swept by the rains from more elevated situations, are often remarkably fertile.

3. THE FOOD OF PLANTS.

How necessary the retention of water is for the food of plants, will appear from the following circumstances; which also prove that if they have water and air, they will vegetate freely without any great abundance of manure, that is, carbon and hydrogen, or vegetable matter, in the soil. For experiments shew that plants will grow in moistened substances, from which they can dissolve or decompose nothing; such as woollen cloth, moss, river sand, litharge, flowers of sulphur, metal, and even shot corns; and nothing supplied to them but a regular quantity of distilled water. Seeds sown in such media have germinated, passed through all the gradations of vegetation to maturity and consequent decay; and yet, when analysed, each part of the plant was as perfect as to ingredients as if it had grown in the most favourable soil; and contained the various earths, alkalies, acids, metals, carbon, sulphur, phosphorus, nitrogen, hydrogen, oxygen, &c. though nothing had been supplied but distilled water. A willow weighing 50lbs. was planted in a certain quantity of earth, carefully covered with sheet lead, and in this

state was kept for the space of 5 years, during which time it was regularly fed with distilled water. At the end of that period the tree weighed 169lbs. 3oz.; though the earth, in which it had vegetated, had lost only 3 ounces in weight. This experiment has been frequently repeated with similar results.

The above experiments demonstrate, that the power of land for retaining water is of the first importance; and that the agriculturist's chief attention should be directed towards it as the foundation of his success. But at the same time he should be acquainted with the component ingredients of the soil; for should he sow such grain as requires for its composition, what his soil does not contain, he must expect a defective crop. If his land, for instance, contain no phosphate of lime, he should not venture on clover, rye grass, saintfoin, and lucerne; if no nitrate of soda or potas, he cannot look for the best barley crop. Though the above experiments seem to prove, that the plant will extract such ingedients from the atmosphere, which is a storehouse of all kinds of effluvia; yet, it cannot be expected that it will obtain a sufficient supply for a luxuriant growth.

Carbonic acid is the pabulum, next to water, of the greatest importance in vegetation. We have in several places shewn that such large quantities of this gas are generated by fermentation, putrefaction, combustion, and the respiration of animals, that were it not dispersed by strong winds, it would in large crowded cities accumulate to such a degree, as to suffocate the inhabitants; and in all places, it would deteriorate the air, were it not for the perfection with which Divine Wisdom fabricated the world, so as to ordain this gas to be the food of plants. And that more might not be generated than they can consume, the Creator gave them the capacity of absorbing a great deal more than the air in a natural state is ever found to contain. For experiments demonstrate, that air charged with one eighth of this gas promotes vegetation; but if in larger proportion, it retards or destroys it. However this is much more than the atmosphere is ever likely to contain, a thousandth part being considered as its specific quantity. Therefore we need be under no apprehension of there being more generated than the vegetable kingdom can consume, and that the superabundance should prove fatal to animal life; for, as long as the wind blows to disperse and blend it in the atmosphere, or remove it from our dwellings, so long will the consumption of vegetables keep pace ith its production.

But plants have two means by which they supply themselves with this gas. The one is by imbibing it from the atmosphere, by the myriads of little mouths or spiracles which are found disposed all over the under sides of the leaves, and sometimes upon the stalks. Plants growing in elevated situations, as on the summits of primitive mountains, where the carbonic acid is in very small quantity compared with the plains, are remarkable for their hairiness. They thus inhale it, and thence it is carried into the sap vessels, where it is blended with that fluid. The other means is by the office of the roots, which pump it up from the soil along with the water and the other ingredients of the sap. The following experiment proves that the luxuriance of vegetation principally depends on the quantity obtained from this source. Two beans were planted in two pots; the soil in the one pot was moistened with water only, and that in the other with water and carbonic acid; the plant in the latter appeared above ground nine days earlier than the other, and produced 25 beans; while the one that had water only produced but 15.

The principle on which manure promotes vegetation, is, its continually kneading the soil with water and carbonic acid, and thus furnishing a constant supply to the roots of the plant. The mode in which manure is generally prepared, is, by disposing a quantity of animal and vegetable productions in a heap, in the open air, when moisture is supplied by the rain; and as it is a law of Nature that her electric energies be never dormant, where they have a conductor to act as a solvent, which in this case is moisture; so the elementary particles of carbon, hydrogen and oxygen begin to form a closer union, and heat is evolved, which hastens the process of dissolution throughout the whole mass. Though this system may be practically of great advantage by accelerating the process of decomposition, and enabling the *Agriculturist* at the least expence to reap a more immediate profit from his manure; yet, it is theoretically bad;—for, should there be a free access of air, then the manure is abundantly converted into carbonic acid and water, which escape into the atmosphere, and to himself is comparatively lost; though it is no loss to his neighbour, or to the great labratory of nature. Now as manure principally promotes the growth of plants by supplying the roots with carbonic acid; the earlier, therefore, that it is laid on the glebe, the better; in order that the soil may become kneaded with the acid as it dissolves, and that the crop

may have the benefit of the whole. However as this can only be done in some cases, and for other purposes dissolved manures must be used, the *compost* is the most frugal and useful of all preparations. For by mixing up a quantity of hungry, earthy materials along with the undissolved animal and vegetable substances;—while the latter are converting into manure, the former imbibe the carbonic acid which would otherwise escape into the atmosphere, and the whole becomes nearly as rich as an equal weight of manure.

4. GERMINATION.

We are now arrived at the operations of that unknown principle called *Life*. That plants should be propagated from seeds, and even slips and cuttings, is what might be, in some measure, expected; since it is a mere increase of the vital spark: but there are certain instances of what may be called equivocal generation in the inferior kinds of vegetable productions, as also in the lower orders of animated beings, which call forth a degree of wonder. There are also certain instances of electric or chemical combinations, which almost induce the belief that vegetable life is not far removed from the mere result of the electric energies. The marks caused by the presence, or left by the passage of the positive electric fluid, have somewhat of the apparent ramifications of a leaf or branch; while those of the negative more resemble the roots of plants; being either bulbous or in mere converging or diverging streaks. The precipitations known by the names of the Arbor* Diana and Arbor Martialis, and that late discovery† of Professor Maschmann of Christiana.

* "Form an amalgam with four parts of silver and two of mercury, and dissolve this amalgam in diluted nitric acid. Then add water to the solution, equal to 30 time the weight of the metals employed, and put the whole aside for use. If an ounce of this solution be poured into a phial and a small piece of soft amalgam of silver be dropt in, filaments of reduced silver will shoot from it, and extend upwards in the form of a shrub. The appearance of arborescence is called *The Tree of Diana.*" Parkes' Ch. Cat.

† "A glass tube is to be bent into a syphon, and placed with the curve downwards, and in the bend is to be placed a small portion of mercury, not sufficient to close the connexion between the two legs; a solution of nitrate of silver is then to be introduced until it rises in both limbs of the tube. The precipitation of the mercury in the form of an arbor Diana will then take place, slowly only when the syphon is placed in a plane perpendicular to the magnetic meridian; but if

Also the finely pulverized ashes ascending from the crater of a volcano, sometimes, in the middle, present the appearance of a finely spreading plane-tree. The most nearly allied to these is the *mould* on putrefying animal or vegetable substances, the dry rot, and fungi. Again, the top of a new brick or stone wall, and even the walls of a house built with stone but recently extracted from the bottom of a quarry many feet below the surface of the earth, will often become as green as if painted. When this colouring matter is examined with a microscope, it proves to be a fine silky pellicle, consisting of the minute buds of a moss, which die with the first dry weather. Such brick or stone walls afterwards become covered with a coat of lichens considerably thicker than the first, which in their turn decay and furnish soil for a succession of larger mosses, and afterwards plants of stronger growth or tufts of grass. Add to these, that plants grown in climates of the same temperature, whether on the tops of the Andes under the torrid zone, or in Lapland, are, according to Humboldt, in a great measure of the same class. The shrub *arbuta uva ursi*, is a native of Scotland, Switzerland, and Canada.

The origin, of some of the above, seems so far doubtful as to appear like a new creation; though others may have sprung from seed dispersed by the wind; while the seeds of the rest may have laid dormant in the bowels of the earth, which, being excluded from the air, never before germinated. An instance is recorded of some white mustard seed, lately dug up with some alluvial soil in America, which immediately grew luxuriantly, though it was ascertained that it had been buried two hundred years. Some wheat, found inclosed with an Egyptian mummy, was quite fresh and grew as well as if it had been the produce of the preceding harvest; though it must have been entombed or thus excluded from the air, at least two or three thousand years. When most soils are broken into, they generally produce a large crop of weeds never before known in that place,

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it be placed in a plane coinciding with the magnetic meridian, the action is rapid and the crystallization particularly beautiful, taking place principally in that branch of the syphon towards the north. If the syphon be placed in a plane perpendicular to the magnetic meridian, and a strong magnet be brought near it, the precipitation will recommence in a short time, and be most copious in the branch of the syphon nearest to the south pole of the magnet." N. M. Mag.

but which gradually give way to cultivated plants. Coarse grass may generally be destroyed by a good dressing of quick-lime, and a finer herbage produced. While the beds of rotten stone in the magnesian limestone, with several other instances, will in a few years produce, when laid on arable land, a luxuriant crop of rank weeds of peculiar kinds.

The most intelligible kind of germination, and therefore that to which we shall confine our attention, is that of seeds. All seeds consist of an outward coat or covering; and an internal white substance called the parenchyma, which, as we have already stated, consists of fecula, mucilage and oil. It is sometimes, as in wheat, barley, oats and all the grasses, of a piece; but it is oftener divided into two lobes called cotyledons, as in the bean, lupin, &c.; and occasionally into three, and in some seeds into six. The cotyledons are divided by a darker coloured string called the radicle, from its forming the root of the young plant.

When the seed is buried in the earth at a temperature above 40 degrees, it absorbs moisture which produces the saccharine fermentation. The warmth thus occasioned seems to be to the plant what it is to the egg during incubation, the resuscitator of life. The swelling of the parenchyma, and the enlargement of the radicle, which now forces the cotyledons asunder, burst the seed; and the radicle, protruding two or three fangs, strikes them into the ground. But while this is going on, another part is also developing itself, by protruding upwards, called the plumula, which seems to be a continuation of the radicle inclosed within the lobes, and which now forms the upper part of the plant. During this time, the parenchyma with the absorbed moisture furnishes sustenance; and the cotyledons, as soon as they rise with the plumula to the earth's surface and come in contact with the air, are converted into thick clumsy leaves; which continue in vigour, till such times as the leaves on the plumula are not only developed, but have attained such strength as to perform the office of respiration; when the cotyledons in general, having spent their parenchymatous matter, fall off.

The plant being thus far advanced, the underside of the leaf will be found very rough, uneven, and covered with a beard or down to catch the moisture as it rises from the ground by evaporation, and attract all the carbonic acid gas that comes near. The upper side of the leaf, likewise, is beset all over with an infinite number of spiracles or mouths of vessels; but as these

vessels are only intended to carry off or assist the escape of the oxygen gas, that side of the leaf is accordingly smooth, so that more facility may be given to its delivery.

5. ORGANIZATION.

THERE is a great analogy between the economy of plants and animals; the leaves in the former performing a similar office to the lungs in the latter; while the roots supply the sap in the same way that the lacteals pump up and convey nourishment to the blood. Sap and blood are therefore to a certain degree analogous, and each has its appropriate system of vessels, whether in the stem of the plant or body of the animal. In such plants as are yearly renewed, these vessels are disposed throughout the whole stem; but in trees, they are chiefly contained in the bark; yet as the bark is annually renewed, the principle is the same. The bark is composed of the epidermis, the parenchyma, and the cortical layers.

The *Epidermis* is the external covering of the plant. In some plants it is a thin transparent substance, having the fibres crossing each other like network, thus giving strength to the whole. But in others, as in the stems of corn, in the reed, cane, and the grasses, it is mostly glassy and white; it is chiefly composed of a thin pellicle of silica;—hence the sharpness, hardness, and strength of such stems. In evergreens the epidermis is composed of a resinous substance, and there are some plants wherein it is formed of wax. In such cases, it serves as a varnish to protect them from the inclemency of the weather;—resin or wax having very little affinity for water. But while the epidermis thus forms a protection against too much moisture; it is also of such a texture as to prevent too great evaporation by the heat of the sun, and thus performs a double office.

The *Parenchyma* is the thin, green rind that is immediately beneath the epidermis. It extends over all parts of the plant; and where the epidermis is not found, as in the leaves, the parenchyma gives the visible green colour. The parenchyma contains the largest tubes in the tree, which seem destined to receive the substances secreted from the sap.

The *Cortical Layers* are immediately next the wood. They contain a great deal of tannin and gallic acid, and are filled with the vessels that convey the sap after it has been elaborated by the leaves. By them the digested sap or secreted substances

are regularly spread over all parts of the tree, and deposited in the vessels of the parenchyma, where it lays the rudiments of incipient wood, or fills the kernel of the seed, or parenchyma of the future plant.

Next to the cortical layers is the wood called the *Alburnum*; and in this are the vessels in which the sap ascends. Wood is composed of woody fibre, mucilage, and resin. The fibres are of two kinds, and are differently disposed. One set runs up and down in the tree, and forms what is called the *silver* grain. The fibres of the other are concentric, running round the tree, and are called the *spurious* grain. They form layers, which, when the tree is cut horizontally, appear like so many concentric circles from the pith of the tree. By their number, the age of the tree may be ascertained, as one of them is produced every summer in the parenchyma; and the next summer is converted into the outermost layer of the alburnum. No sap, except in the oak and some few others, ever rises in the innermost layers of the alburnum, which form what is called the heart wood; hence we find the heart wood in a great many trees completely decayed, and the tree hollow; while the vegetation and formation of new layers of the alburnum are going on as vigourously as ever. But in the oak, where the vessels, though very minute, still continue in the very centre of the tree to convey some sap, the heart becomes and continues the most firm and durable part of the wood.

Thus then the alburnum vessels take the sap from the roots to the leaves where it is elaborated; and the vessels of the cortical layers receive it and convey it all over the tree, filling the tubes of the parenchyma. This is the progress of the sap in one summer; but it does not appear that any sap is returned in the autumn to the roots, more than what is elaborated to increase their bulk proportionately with the rest of the tree, so that it cannot be said to have undergone a complete circulation.

6. FRUCTIFICATION.

THE design of all the beautiful flowers, with which we see the earth bedecked, is, by their peculiar organization, to lay the foundation of the seed from which the future plant is to come; and the pulp or soft esculent part of all fruits, called the *pericarp*, is the mere protection of that seed.

Every flower generally consists of the outer green cup called the calyx, and the corrolla or petals, being the leaves whereon the beautiful colours are depicted. At the bottom of the corolla is the nectarium, or the place where the honey is secreted; and which is the seat of the germen, wherein are laid the first rudiments of the young seed. The calyx seems a fine extention of the parenchyma and the corolla of the cortical layers; and are evidently designed to protect and assist a very delicate extension of the pith of the wood which arises from the germen, called the pistil. The stem of this pistil is hollow and is called the style. At the end of it is a knob or head covered with a gummy substance. Besides this pistil, there is another stem rising from the germen or bottom of the cup, called the stamen. Its head is differently shaped from that of the pistil, and is provided with a fine yellow dust called the pollen. In process of time this pollen falls upon the head of the pistil; and, being retained by the gum, is thence carried down its style to the germen, where the young seed begins to be formed. The germen afterwards becomes the pericarp.

In most plants there are more stamens than one; and in some, the pistil and stamens are not in the same flower, but in different flowers on the same plant. Sometimes all the pistils are in one plant, and all the stamens in another; and in some plants there are no seeds or flowers developed. Every species of plants has in this respect a peculiar conformation; and on this peculiarity the Botanist and Natural Historian has seized as the distinguishing characteristic of the different classes. By this means all plants are divided into 24 *classes*. But as each contains different kinds of plants, they are subdivided into *orders*, of which there are 121. The various kinds of plants are called *genera*, of which there are enumerated above 2000; but as most of the genera have different variations; so they are subdivided into species, of which there are above 30,000. The foundation for genera is in a difference in the nectarium; and the difference with regard to the root, trunk, and leaves, forms that of the species. But among the species are distinctions without number:—they are called *varieties*.

Those flowers which have but one pistil, and but one stamen form the 1 class, called *monandria*; those with two stamens form the 2 class, *diandria*; and so on to the 11 class, which includes all that have from eleven to nineteen stamens. 12. *Icosandria* have 20 or more stamens, and they are inserted upon

the calyx or corolla. 13. *Polyandria*, include all that have more than 20 stamens, without the above distinction. 14. *Didynamia*, four stamens, two long, two short. 15. *Tetradynamia*, six stamens, four long, two short. 16. *Monadelphia*, filaments united at bottom, but separate at top. 17. *Diadelphia*, filaments united in two sets. 18. *Polyadelphia*, filaments united in three or more sets. 19. *Syngenesia*, filaments united and five stamens. 20. *Gynandria*, stamens inserted on the pistil or on a pillar supporting the pistil. 21. *Monœcia*, stamens and pistils in separate corollas upon the same plant. 22. *Diœcia*, stamens and pistils in distinct corollas on different plants. 23. *Polygamia*, various situations, stamens only, or pistils only. 24. *Cryptogamia*, stamens and pistils invisible or no flowers.

On the distribution of the pollen depend a great many, if not all, the varieties found in the different species, and perhaps in many genera; for when the pollen of one species of a genus is removed and placed upon the head of the pistil of another, the seed and future plant are indistinct, partaking of the nature of both. By this means the species of apples are now, by the horticulturists, multiplying without number; and some assert that such innovations are necessary for maintaining the perfection of the fruit. Varieties in wheat, peas, and a number of plants, have already been produced; and thousands of experiments of this kind are at present going on. The wind also, in part, performs this office; but the plants belonging to the 21 and 22 classes, are supposed to be generally indebted for this distribution to bees and other insects, that enter the corolla to extract the honey from the nectarium, carrying away the pollen on their downy bodies, which is gathered off by the gummy heads of the pistils when they enter another flower. Bees-wax seems to be this pollen, kneaded into a paste with the gummy substance of the pistil. But even in flowers that contain both the pistil and stamens, Nature is not without contrivance in the fructifying process;—for it is found that when the pistil is shorter than the stamens, the flowers grow upright, so that the pollen may descend upon the pistil; but if the pistil is longer than the stamens, then the flower hangs downwards, that the pollen in falling may be caught by the pistil. Contrivance is the mark by which Nature's works may be known!

7. VEGETABLE CHEMISTRY.

We have hitherto been describing only the mechanical parts of plants, their operations and productions; we have not yet touched upon the secretion and formation of those substances. This is the chemical part of vegetation, and depends upon the electric energies or heat the connective medium between *life* and the simple substances.

Several experiments tend to prove that the electric energies, though certainly not vegetable life, perform a very important office in vegetable economy, no less than that of acting as the vehicle of life. It is found that seeds will neither germinate *in vacuo*, nor in the absence of oxygen. At the same time, they will not germinate in water charged with negative electricity; but will do it more rapidly in water charged positively than under ordinary circumstances. Plants also, charged with the negative fluid from a machine, wither and decay; but grow luxuriantly when charged with the positive. We have, Chap. XVI. s. 1, stated that the air is sometimes negative and sometimes positive; but that the earth is always negative; now observations demonstrate that plants never shoot in spring, or at any time make any great shew of vegetation while the air continues negative, even though the solar rays fall direct upon them; but in the very depth of winter, they will vegetate when the air is positive. And in the spring, when the air has been positive for some time, and vegetation is rapidly advancing, no sooner does the wind change or the air become negative, than it comparatively ceases. A *Blight* is said to be the spawn of insects, "Brushed from Russian Wilds," that eat up vegetation. Such blights generally come with a dry blue mist, or blue tinge in the air, that is sometimes attended with a smell resembling that which is occasioned by an electric spark. May not this be carburetted hydrogen gas evolved from the earth by a charge of the negative electric fluid, and condensed into a locomotive charge, or liberated in the spring more particularly, on account of the sun advancing towards the northern hemisphere? Certainly, insects are generated in myriads after the wind has brought the blight; but then, may not the electric charges have produced a disease in the plant, or a fermentation of its juices, causing a developement and exudation of the saccharine matter, in the form of what is vulgarly known by the name of the *Honey*

dew, which is the cooperating cause of this exuberance of animal life, by affording a nidus to the myriads of ovula of various animalculæ continually floating in the air?

Plants near the foot of thunder rods grow vigorously; and on this principle conductors have been elevated a great height, with the design of attracting the positive fluid from the clouds and conducting it downwards to plants. These conductors were supported by non-conducting substances fixed into the ground, so that they did not come in contact with the earth or plants; but the lower part of each branched off into a great many ramifications furnished with spikes pointing downwards; consequently, the electric fluid was distributed to different parts of the garden. The result, in most cases, is said to have fully answered the expectation of the experimentalists; and to have proved, that the principles of electricity are those on which vegetation chiefly depend. The leaves of plants act as so many spicula to attract the electricity of the air and solar rays:—hence very high trees are so many natural conductors, attract a vast quantity of the electric fluid, and consequently put forth a luxuriance of foliage proportionate thereto. It is a well known fact that positively charged winds are colder to the leeward than to the windward of plantations or forests of high trees, by being thus deprived of their electricity.

The ascent of the sap in the tubes of the alburnum may more reasonably be supposed to be occasioned by the electric energies, than by any inherent power in the plant similar to muscular contraction. Should a small capillary tube be placed with the lower end in water or any other liquid, the fluid substance will ascend but a very little way; but if that tube be electrified, the liquid will immediately ascend very rapidly along it. The lower regions of the air, in winter, being mostly negative, and the solar rays having little effect, no sap therefore rises in their tubes; and the only sign of life which they exhibit, is, the protrusion of a small quantity of mucilage into the buds, which may be the last ebbings of the previous summer's sap;—and if they be carefully observed, it will be found that even this is done on those occasions when the air is positive.

The art of making microscopes has now arrived at such perfection, that by their assistance Nature has actually been detected while busy in the process of vegetation. The extension of a blade of wheat was rendered visible. Little globules of sap were observed ascending from the roots along the tubes. These,

when they came to the surface of the plant or in contact with the air, exploded and deposited their elementary materials in the blade. Now it is ascertained that all vertical bodies are positively charged at the top and negatively at the bottom. The sap therefore of a plant, having arrived at the extremities of the ramifications of the trunk, comes in contact with positive electricity; and being chiefly a mixture of carbonic acid and water, these substances are decomposed. The carbon of the acid and the hydrogen of the water take in their full complement of their inherent positive fluid, while the oxygen from both unites with the negative; the sap is thus elaborated, and fitted for the process of vegetation. This is nothing more than what is exemplified in the galvanic apparatus. When the wires are placed in diluted acids, both the acids and the water are decomposed, oxygen gas is dispersed from the positive wire, and the hydrogen, &c. from the other. Hence the rays of the sun, and even the air itself being positive, charge the top or leaves of the plant, and by the peculiar decomposing energy of the electric fluids, (the bottom of the plant being negative from the earth by induction,) the superabundant oxygen is dispersed to renovate the vital principle of the atmosphere; while the remainder combines with the carbon and hydrogen to form the peculiar vegetable substances, which are now deposited by the channels of the cortical layers, as already stated, in the parenchyma, according to the inscrutable laws of vegetable life.

Plants that are exposed to the solar rays, are found to give out both carbonic acid and water by night. The fluids arising from the roots, being put in motion while the sun shines, do not arrive at the leaves before there is no positive fluid for the decomposition; and therefore they are poured out undecomposed, thus contaminating the air which they had previously cleansed. Also plants that are made to grow in the dark are colourless; and when burnt, give out no flame;—they contain an excess of aqueous matter, but no oily or resinous substances. Also plants growing in air, that contains hydrogen gas, attain a brighter green than under ordinary circumstances; and if growing in the dark, where this gas is present, they are said to assume somewhat of a greenish colour. From this it appears, that plants can only in part by their own power decompose water and carbonic acid, especially the former; and that the rays of the sun or positive electricity are absolutely necessary to enable them to effect a perfect decomposition:—for though carbon and

hydrogen are in the saccharine matter of these plants, yet they are so oxided as to become almost incombustible. Hence it seems, that light becomes a component part of all plants, and it is ascertained that different rays perform different offices. The rays at the red side of the spectrum are productive of inflammability in the various substances; combining with the elementary particles, or supplying them with their peculiar charge of the inherent positive fluid, and dispersing the oxygen gas; while those at the violet side produce the green colour, by causing a combination or retention of oxygen on the surface of the plant, and thus occasioning nearly an equal quantity of both positive and negative rays to be reflected. If two plants therefore be made to grow, one at each side of the spectrum; that near the red, will contain combustible substances but little colour; and the one near the indigo, will have colour but no combustibility. See Theory of Light and Heat.

So great is the appetency of plants for light, that if growing in a darkened room with light admitted only by the key hole of the door, they will, if sufficiently near, insinuate their heads through the hole. This is the most remarkable in potatoes. When the remains of a winter store are permitted to continue in the farthest corner of a dark cellar, they will, in the latter end of spring, have, with their long tendrils, made the half circuit of their prison, and have protruded their pale heads through every chink of the door that admits a few particles of light. And so great is the natural attraction between the sun and plants, that all of them turn their faces towards him, or rather the upper side of the leaf or flower is turned in this direction, which imprints on the whole the appearance of a back and front. The sun flower, and certain others, called Heliotropes, follow the course of the sun; so that in the morning the open part of the flower looks eastward; at noon, southward; and in the evening, westward. They have hence been named the poor man's dial. Besides, most flowers either contract or entirely close their petals by night, or when the sun does not shine upon them. From some, especially the nasturtium and the English marigold, faint flashes of light may be frequently seen emitted in the twilight of the evening after a hot summer's day; thus parting with some of their imbibed positive electricity, to the rising negative fluid of the earth.

8. VEGETABLE HEAT.

EXPERIMENTS prove that trees, nearly all the summer, have a mean temperature of about 60 degrees, and no more, even when that of the atmosphere is between 70 and 90; and in winter, though ever so much exposed to the cold, their temperature is seldom lower than 40, even when that of the air is considerably below freezing point. Wherever the vital principle is present, it has the power of resisting congelation; and in vegetables this power seems to depend a good deal on the oily, mucilaginous nature of their substances, and their being divested of the aqueous particles. For at the close of summer, the sap ceases to rise; and what is in the vessels is completely elaborated during the autumn; so that, in winter, they contain little or no water in their composition. In this we detect a wise provision in Nature; for as the rising sap necessarily contains a great deal of water, which besides serving as a vehicle for the other ingredients, is itself a pabulum; and not being decomposed till it comes to the leaves,—were it not for this cessation, the intense frosts of winter would make dreadful havoc among trees. For exhausted as they are, and great as the vital energy may be, it is not on all occasions able to resist the expansive force of the congealing power. In cold climates, and even in the north of France, the trunks of trees are frequently rent during intense frosts; and, in severe winters, instances are not wanting in our own country.

That plants should have a temperature greater than the medium in which they exist, must be wholly ascribed to the vital principle. But that their temperature should not be above 60, when the air is 80, depends perhaps on their peculiar economy. The vegetating process is such as must necessarily produce cold. For by its operation the electric fluids are made to re-enter their respective vehicles; when, of course, they become latent or do not produce heat. Water and carbonic acid are decomposed; the superabundant oxygen is sent off with its full charge of the negative electric fluid; and the carbon and hydrogen are elaborated into the vegetable substance with nearly the full charge of the positive fluid:—hence their inflammability. Now in this process it is evident, that as much of the electric fluids have been gathered from some source, as is equal to the quantity of caloric, which would be produced by

the combustion of that vegetable substance, or by its re-combination with the liberated oxygen gas. It is plain, therefore, that during the process of vegetation, either an equal quantity of caloric is decomposed, or, that plants gather these charges from the uncombined fluids of the earth and atmosphere; and that, in either case, the vegetating process must be productive of cold.

Hence we see that the office of the vegetable kingdom, in the Economy of Nature, is to renovate the vital principle of the atmospheric air; which is done by liberating the earth's electricity, producing a kind of resurrection in the effete or dead oxygen. We are at a loss which to admire the most, the ingenuity of the contrivance or the benevolence of the design. But indeed, every step we advance towards the secret sources of Nature, is but immerging so much the deeper into the Light which emblazon's this Truth, viz. "That a GODHEAD reigns, and that His most distinguishing attribute is LOVE."

CHAP. XIX.

Mechanism of the Human Frame.

1. Animated Nature. 2. Animal Substances. 3. Bones. 4. Muscles. 5. Blood Vessels. 6. Lungs. 7. Organs for Assimilating the Food. 8. Absorbent, or Lymphatic System. 9. Glands. 10. Internal Parts of the Body and their Disposition. 11. External Padding and Covering. 12. Brain and Nerves.

1. ANIMATED NATURE.

We come now to those bodies wherein Nature seems to have put forth all her skill in the work of organization. Vegetables are a kind of half animated beings, forming the link between unorganized matter and the animal kingdom. For some of the fungi and lichens are so little removed from mineral substances, as to be hardly worthy of being classed among organized bodies. On the contrary, other vegetables are so perfectly formed, that they seem endowed with a sensibility equal to some animals. Such is the plant called Venus' Mouse-trap, which if an insect comes into, it closes, stings it to death, and feeds upon it. If they want locomotion, there are some classes of animals, not much better provided for in this respect, as certain shell fish, among which is the oyster.

But the zoophite called the *polype* is considered as the connective link between the animal and vegetable kingdoms. This vegeto-aquatic animal, may be propagated by slips and cuttings. For in how many parts soever one is cut, each section becomes a perfect polype. If one have a number of slits made in it, each

division becomes a head,—all of which feed, though they have but one body. If seven slits be made we have a true *Hydra;* if each of these be slit again, we have fourteen heads to one body. Should each of these be cut off, new ones spring up in their places; and the severed heads will each become a polype. Should one be turned inside out, it will in a few days become as perfect as before. If the head of one be placed on the body of another,—they form one polype which lives and feeds as well as any other. If two be closely compressed, they become one: or if the one be thrust down the throat of another, so that their heads come in contact, they will equally unite. A polype can swallow a worm larger in bulk than itself.

But as animals were designed to move from place to place, and the roots by which they receive nourishment are no less numerous than those by which vegetables are supplied with aliment; it is necessary that the medium from which they gather nourishment should be carried about with them. Therefore they are provided with a bag called the stomach, wherein is placed this source of support, or food, which, having undergone certain preparatory processes, is gradually submitted to the roots. Besides the office already mentioned, which vegetables discharge in the great economy of Nature, they seem to have been originally designed for the food of animals; since without their aid, the elementary substances which constitute the animal frame could hardly have entered the system, without this travelling bag, being always encumbered with a ponderous load of earthy materials. Whereas by the vegetable economy, these substances are separated; and only such enter the stomach as are capable of being converted into the animal substance;—hence vegetables may be considered as the connective link between the animal and mineral kingdoms.

The chain of animated Nature from those inconceivably small animals, mentioned at page 205, to the ponderous mass of the whale, the unweildy bulk of the sagacious elephant, or the union of a more perfect organization with Mind in the composition of Man, consists of so many links, and these of such variety of form, that it would be useless in our prescribed limits to attempt to offer remarks upon them; but as we conceive the process by which matter is elaborated by life to be nearly the same in principle, in all cases, though the most perfectly known in man, we shall content ourselves by endeavouring to render this process intelligible.

2. ANIMAL SUBSTANCES.

THE elements which principally enter into the composition of animal substances, are carbon, hydrogen, nitrogen and oxygen. Nitrogen is considered as the peculiar element of animalization, or that which is used for converting vegetable into animal substances. But vegetables contain very little nitrogen, and some none at all. An animal inspires it along with the draught of vital air, but is found to respire the whole without the least deduction; yet its flesh, though it feeds on herbs containing none of this element, is nevertheless found to contain a great deal. This curious fact is admitted as an argument in favour of the compound nature of nitrogen; and of its being formed by the agency of animal life from oxygen and hydrogen, or from hydrogen and some unknown metallic base.

The other elementary substances most predominant in the animal kingdom are calcium and phosphorus, generally combined by the intervention of oxygen, as phosphate of lime, of which the earthy part of bones is composed. Hair contains iron, but it is not known in what state, also the oxide of manganese, a small quantity of carbonate of lime, silica, and sulphur; the colour depends on an oil, probably containing sulphate of iron, white and red hair have an excess of sulphur, but become black with the oxides of the white metals. Nails are coagulated albumen, contain very little earth, are attached to the epidermis, and come off with it. Silk, hoofs, horns, and beaks, claws, and feathers of birds are much of the same composition of hair and nails, albumen or gelatine forming the chief of the mass. All animals that have shells have no bones; the shells of those called testaceous consist of carbonate of lime; but the crustaceous contain also phosphate of lime. Mother of Pearl and Pearl contain 66 carbonate of lime, and 34 of membraneous substance. White coral 50 carbonate of lime, and 50 animal matter. The proportions in the Red Coral are 53½, and 46½. Eggshells consist of carbonate of lime 89·6, phosphate of lime 5·7, gluten and moisture 4·7.

What are more peculiarly called animal substances, are gelatine, albumen, and fibrine. That these substances are so few, is perhaps owing to the delicate texture of the animal arrangement, which cannot be examined before the vital principle is fled, so that partial decomposition is somewhat advanced before

the subject can be submitted to analysis. However this may be, the basis of the skin, nerves, membranes, muscles, and cartilages; also of the fluids, as blood, chyle, milk, mucus, the gastric and pancreatic juices &c. consist of these substances.

Gelatine, jelly, or in a less pure state, glue, is the chief substance in the skin, sinews, and membranous parts of animals. It is obtained from them by means of boiling water. But besides these, it may be extracted from the bones, hoofs, and horns of animals. A very pure kind, called *Isinglass*, is procured from a certain fish. But that obtained from the horns of the hart is the most esteemed; and is generally, on account of its being easy of digestion, and very nutritious, recommended for invalids. The horns are reduced to shavings, whence by means of boiling water, the jelly is more easily extracted. A very great deal of this substance is contained in bones and cartilages, and thus a large quantity of very nutritious food is frequently thrown away. Papin's digester, a kind of pan made very strong and steam-tight, is sometimes used for dissolving it. The bones, with some water, are submitted to a temperature above boiling water, which reduces them to a pulp. But the fuel required is frequently of more value than the jelly obtained. Muriatic acid will detach the lime, and leave the gelatine in the shape of the bone, the acid may be washed out with cold water. Jelly is purified with the white of eggs, which combining with the impurities, and being coagulable by heat, rises to the surface, leaving the transparent jelly beneath. The composition of this substance is as follows:—carbon 67·881, hydrogen 7·914, nitrogen 16·998, oxygen 27·207.

Albumen is composed of carbon 52·883, hydrogen 7·540, nitrogen 15·705, oxygen 23·872. It is a constituent part of most animal substances, but is sometimes isolated in different parts of the system. The white of eggs is almost entirely albumen. The substances which compose the nerves, the serum of the blood, and the white part or curds of milk, are principally albumen. A temperature of 165 degrees, a little sulphuric acid or alcohol, is capable of coagulating this substance; and when once solidified, it cannot by any means be reduced to its former state. In making cheese, the albumen is coagulated by rennet, which is a prepared calf's stomach. A small piece is steeped in water, and then a little of the fluid is put into the milk, which has a temperature of 50 or 60 degrees. Rennet is supposed to

owe this property to the presence of gastric juice remaining in the coats of the stomach.

Fibrine is the principal substance in muscles, or what is called the lean flesh of animals. When the muscles are cleansed from the red particles, which give them their colour, they consist of a complete tissue of something having the appearance of fine white threads, fastened together and softened by gelatine. From their appearance they are called *Fibrine*. This substance is also found in the blood along with albumen and colouring matter. It is insoluble in water and alcohol, but is dissolved by sulphuric acid, and converted into a gelatinous substance:—it is composed of carbon 53·36, hydrogen 7·021, nitrogen 19·934, oxygen 19·685.

Animal Oils consist of carbon and hydrogen, with a small portion of nitrogen and oxygen—or gelatine. Tallow and all the fat of animals, as well as butter, are oils;—but the last contains a considerable portion of oxygen.

The *Animal Acids* are all formed by the decomposition of other substances, or are found in the secretions. They consist of a triple base, viz. carbon, hydrogen, and oxygen; except lactic acid, which has only a double base and has already been mentioned.

Laccic acid is procured from a substance called white *Lac*. It is a reddish fluid, rather bitter, and salt to the taste, but not sour. It forms small needle-shaped crystals; and being dissolved in lime water, it assumes a green colour. *Lac* is somewhat similar in its formation to bees-wax, being collected from flowers by an insect in the East Indies, for the purpose of protecting its eggs. It is principally employed in making sealing-wax and varnish.

Prussic acid contains no oxygen, but is classed among the acids on account of its readily uniting with the alkalies. It is obtained from several substances, but especially blood, by heating it with caustic potas; a prussiate of potas is thus formed, from which the acid is afterwards precipitated. But this acid has lately been discovered in many parts of the vegetable kingdom; as in the leaves of the bay, or laurel, in the kernel of the bitter almond, as well as in the kernel of many stone fruits; and though a deadly poison, is highly valued in cookery. It is colourless like water, and does not affect vegetable blues; yet combined with the red oxide of iron, it forms the well known colour called *Prussian blue*.

Sebacic acid is procured from animal oils, in all which it is plentifully formed by mere exposure to the air. It is liquid, of an acrid, sharp, bitterish taste; but may be crystallized in needle formed crystals. It combines with the metallic oxides, and mixed with nitric acid, dissolves gold.

Uric or *Lithic* acid is found in human urine; also in human calculi, some of which are composed almost entirely of it; and likewise in the concretions called chalkstones formed on the joints of gouty persons. These concretions are for the most part uric acid and soda. Like the other animal acids, it is composed of carbon, hydrogen, nitrogen, and oxygen, but it is destitute of taste or smell. It may be crystallized in small red crystals with brilliant facets; turns vegetable blues to red; and when dissolved in nitric acid, stains the skin a pink colour.

Milk consists of gelatine, albumen, oil and water; and in common processes is separated into cream, curds and whey. The cream is chiefly animal oil; the curds, albumen; and the whey, water and gelatine. Milk also contains phosphate of lime.

Blood contains fibrine, albumen, gelatine, hydro-sulphate of ammonia, soda, sub-phosphate of iron, muriate of soda, phosphate of soda and phosphate of lime, benzoic acid, with a considerable quantity of water; and, according to Sir E. Home, two cubic inches of carbonic acid gas to each ounce of blood. The colouring matter of blood, when reduced to ashes, consists of oxide of iron 50, sub-phosphate of iron 7·5, phosphate of lime with magnesia 6, lime 20, carbonic acid and loss 16·5. The blood of the ox differs from human blood in containing less saline matter, and more nitrogen. When blood is permitted to stand, it separates;—the colouring part or crassamentum separating from the serum; the proportions of these vary in different animals;—the blood of predatory animals, as of the dog, contains the most crassamentum; then that of man; while it is the least in the timid sheep and other imbecile animals.

Having given this short account of the principal animal substances, before it can be shewn how animalization is carried on, it will be necessary to describe the whole superstructure. And as a knowledge of the human frame is what the most concerns us, we shall confine ourselves to it, making a remark where there is any thing very striking in any other animal. The principal parts of the human body, are, the brain and

nerves, the lungs and blood-vessels, the stomach and organs for assimilating the food, with the nutrients; the absorbents and glands for cleansing the system, and the bones for the prop-work of the whole, with the muscles and sinews that move them.

3. BONES.

The bones are the most solid part of the frame, and in a great measure determine the shape and dimensions. They are composed of gelatine and phosphate of lime. This salt consists of 48½ lime, and 51½ phosphoric acid; which acid is composed of 46½ phosphorus, and 53½ oxygen; and the earth of 20 calcium, and 7½ oxygen:—so that 100 parts bone, without gelatine, will consist of 30¼ of calcium, 24 phosphorus, and 45¾ oxygen.

While the animal is in the fœtal state, the incipient bones are merely a gelatinous membrane of a loose, spongy texture, in the cavities of which the phosphate of lime is gradually deposited. Milk contains the most of this salt near the time of parturition; and as the child's digestive organs are formed, it gradually diminishes in quantity; yet does not entirely cease till the bones are, not only well set, but also the teeth are protruded from each jaw, which are phosphate of lime enamelled with a fluate of the same earth. The disease in children, called *Rickets*, proceeds from a want of phosphate of lime in their bones; which are consequently not sufficiently strong to support the fleshy parts of the body. Hence the necessity of mothers suckling their own children; or, at least, of procuring a nurse who bore a child nearly at the same time with herself. For the formation of bones after this period, it is obtained from bread and other farinaceous substances; but especially from that of wheat flour, which contains more of this salt than any other vegetable substance. In manhood, when the bones have attained their full growth and strength, the phosphate of lime is no longer assimilated.

As neither the white, nor the yolk of eggs contains phosphate of lime, it was necessary that it should be placed somewhere about the egg, in order that the bones of the young bird might be formed. It is therefore found in the shell; and being therein deposited, another useful purpose is answered, no less worthy the wisdom of the great Contriver. While the bones are forming, the

shell is gradually weakened, so that in due time the young animal has power to break it, and thus liberate itself. Fowls that are kept where they cannot procure calcareous matter, are said to lay their eggs without shells.

The *gelatine* found in bones is partly dispersed throughout the mass, but is principally employed in forming the cartilage, or the smooth, elastic, bluish substance at the joints. The ends of the bones, being overlaid with this, are by its smoothness and elasticity, and its being lubricated with a peculiar liquor secreted for that purpose by the glands, made to move in the joints and sockets, not only without friction, but with the greatest facility. However, were these bones not fastened together at the joints, the structure would still want support; consequently, each joint is tightly bound round on all sides, with a thin, but very strong, elastic membraneous substance, called *ligament*. So that the joints, though necessarily thick, and, were it not for a judicious disposition of the muscles, would appear somewhat clumsy, are as strong as any other part of the limb. The number of bones found in the human body is 248; and they are so contrived, formed, and fashioned, both for strength, and with hinges, pivots, loop holes, grooves, protecting angles, and facets, to suit all contrivances, that volumes might be written on this subject alone.

4. MUSCLES.

THE muscles are the organs that produce motion. They are bundles of fibres possessing the power of contraction and dilation; and are composed of fibrine fastened together by gelatine; and each bunch terminates in a cord of gelatine, called the sinew or tendon. A muscle is divided into three parts, the head, belly, and the tail. The head is firmly attached to the bone, in, or towards, the trunk of the body:—the place of attachment is called the origin; the belly is the place of contraction, and therefore merely adheres to the contiguous softer and pliant parts; the tail or sinew extends to that bone which is to be moved, and to which it is firmly attached at the place called the insertion. The fibres are variously arranged, according to the direction in which the pull is required. The joint or the head acts as the prop, the bone moved as the lever, and the contraction of the muscle is the power. The muscles, which mostly terminate in extended sinews, are those which move the

limbs, or extend to the extremities of the body. For, by having a cord attached to them, the muscle may be placed at a considerable distance from the limb to be moved, and thus a great inconvenience is obviated. For instance, if the muscles that are to move the hands or feet were placed in the palm of the hand or sole of the foot, not to mention the clumsy appearance which they would give, they would counteract themselves, or be in each others way; they are therefore placed at the swell of the arm or in the calf of the leg, and sinews lead from them to the hands and feet. And that these sinews might not start up, stretch the skin or make the limb appear unseemly, they either wind round the bone, or are tightly strapped down by strong ligaments, at the wrist of the hand, or at the bend and top of the foot.

However it should be observed, that the power of the muscle rests alone in contraction, for the dilation proceeds from a mere cessation of exertion. But to remedy this, muscles are always placed in pairs, one to counteract the other; so that if the limb is bent by the contraction of one, it is made straight by a like contraction of another. Every movement in the human body, therefore, depends on the contraction of some muscle; and when we consider the variety of motion which we are capable of producing, we cannot but wonder where all these muscles are placed; and how they are disposed, so as not to interfere with each other. For the contraction of a muscle is towards its centre, where it gathers, as it were, into a round ball;—two, therefore, placed near each other, may have room enough while at rest, or while one only is contracted; but there may not be room for both to contract at the same time. Yet none of the muscles of the human body, and there are no fewer than 446 well described with appropriate names, are found to interfere with each other, except in one solitary instance;—when we gape, we cannot swallow; which is said to proceed from the muscles necessary to produce each action being placed so near together, that both classes have not room to contract at the same time. Yet no doubt this was contrived to answer some useful end which is not yet discovered.

These short hints may impart some idea of the muscles, but to give a full description of the manner in which they are placed, for the purpose of producing all the pulls that are wanted in every direction, would be an endless task. It is worthy of remark, that what we call beauty in the human form

principally depends upon the muscles. Their disposition in the calf of the leg, the thigh, the arm, and in all other parts of the body, level the bones and hide the swell of the joints, giving at the same time roundness and plumpness to the person. But the bundling up of the fibres differs in every person. In one man they are compact, firm, and neatly disposed; while in another, they are more dilated, and as it were worse tied up, evidently performing their office in a more sluggish manner. Bodily strength also depends upon the bulk, as well as upon the contractive power of the muscles: for no limb can be moved with greater speed or force than the corresponding muscles are capable of producing. Hence, too much fat must clog and encumber the play of the muscles; or, their want of due sustenance occasioned by bad diet, bad air, or any thing that prevents a due support of the fibres, or diminishes the necessary gelatine and emaciates the body, must diminish their bulk and contracting power, and consequently impair the bodily strength.

5. BLOOD VESSELS.

THE vessels which contain the blood are the most important in the body, because in them is conveyed the materials to all parts of the superstructure for its formation and support. They are divided into two sets, arteries and veins. The blood is propelled along the arteries to the extremities of the body by the impulse given it by the heart; and returned back again along the veins by their own muscular exertion.

The heart seems placed as near the centre of the system as possible. It is a kind of hollow muscle, consisting of two layers of fibres, that have a spiral form. One layer winding the contrary way to the other, the fibres cross and intersect; so that this muscular bag can contract its sides by one layer of fibres, and force out the blood along the arteries like a syringe, and by the other layer, can dilate them, and receive into the hollow a fresh supply from the veins. It has four cavities; two of them are called *ventricles*, which are furnished with valves between them and the arteries; and the remaining two, called *auricles*, are furnished with valves between them and the ventricles. From the left ventricle, the blood is propelled into the aorta; which is a large vessel that soon branches off into several others, all passing in the most direct manner to the extremities of the body; and where they necessarily diverge from a straight

line, it is at angles and not in curves. After throwing off a multitude of small vessels, all tapering like the branches of a tree, they lose themselves in the flesh, having degenerated into myriads of invisibly small vessels, called nutrients. The blood being thus dispersed among the fibres, is taken up by the veins. But their commencement is such, that with a microscope it cannot be distinguished from the nutrients. And so evenly are both sets disposed, that we cannot prick the flesh anywhere with a pin without severing a considerable number of them. Hence the blood in them may be compared to the aqueous particles in the atmosphere; which first condense into drops of rain that fall upon the earth, and are collected into dripping rills; these converge into brooks and rivulets, which afterwards swell into branches of large rivers that finally unite and roll their waves in one channel into the sea. So the blood, being collected from thousands of tributary vessels into one large trunk, called the right auricle, is again poured into the heart, after having circulated through the whole body.

In this round, as will be hereafter shewn, it has parted with its supply of nourishment to the body; taken in a load of refuse or effete particles; and just before it entered the heart, received the supply of chyle from the food admitted by the stomach. It must therefore be in a state very different from that in which it left the heart; therefore, having entered the right auricle, it passes within the heart through the valve into the right ventricle, whence by the muscular contraction it is driven to the lungs; and being there elaborated by being every particle exposed to the contact of the atmospheric air, it returns back to the heart by the left auricle; and passing within the heart through the valve into the left ventricle, is thence propelled into the arteries, as we have shewn; and this process or double circulation goes on to the end of life.

The whole blood in the body of a man is from 25 to 30lbs. The left ventricle ejects about an ounce, or near two table spoons full, at a time; and this quantity is driven out by each contraction or pulsation, of which about 4000 take place every hour. From this, it appears, that 4000 oz. pass through the heart, or circulate through the whole body every hour, which is near 14 times as much as the whole body contains; consequently, the whole stock of blood must make 14 complete circulations every hour, or one circulation in about four minutes. It is said to be propelled along the arteries with

a force equal to that given by a pressure of seven feet perpendicular height of water; but along the veins, with only that of six inches. The velocity along the arteries is at the rate of 8¼ inches per second. In large animals, the blood is propelled with greater force. Dr. Hunter, who dissected a whale, states that the left ventricle was a foot in diameter; so that no less than 10 or 15 gallons of blood must be thrown out at every stroke of the heart, with an immense velocity.

The arteries may be distinguished from the veins by their being the seat of pulsation. They are also externally of a red colour, while the veins are blue; and are all hid within the body, either running along inside the trunk, or in grooves of the bones, in such a manner as to protect them from wounds and common external pressures, which might stop the passage of the blood. However some of them terminate at or very near some parts of the skin, as at the cheek, and thus give floridness to the complexion. The veins, in general, lie nearer the surface of the body, and are less guarded. If an artery be cut, the blood spouts from it with the pulsation, or in jets; but if a vein, it flows regularly.

6. LUNGS.

The lungs are the organs into which the air is drawn when we breathe, and wherein it is brought in contact with the blood. They are spoken of in the plural number, because there are two distinct compartments: one lying on the right side of the chest, and the other on the left; so that should one be wounded, the other remains entire, and can perform the office alone.

But that we may the better describe the mechanism of the lungs, we shall commence with the passage leading to them. The trachea or windpipe connects the lungs with the mouth and nostrils. It is composed of a number of cartilaginous ringlets, fastened together by ligamentous fibres; and made so, that nothing without great violence can compress them and stop the passage. Yet these ringlets are not complete circles; but each wants that part next the esophagus, so that the food can descend in that passage without pressing against the unyielding rings. The top of the windpipe, called the larynx, is secured by a valve called the epiglottis, over which every morsel that we eat passes. This valve, situated at the root of the tongue, is full of nerves; so that it is no sooner touched by the food, than it

closes and completely secures the orifice till the whole of the food is passed and clean swept off, when it re-opens; or should we through carelessness open it when crums are near, we are almost sure to draw some in. When this happens, the irritability of the trachea is such that it severely chastises our neglect, by tormenting us with the most violent convulsive coughing till the offensive morsel, which had gone down the wrong way, as we term it, is brought back again. The top of the trachea we explained at page 160; and the lower end, called the Bronchea, has two orifices, each connected with the top of a lung.

The lungs fill almost the whole cavity of the breast. They are broad at the bottom, and terminate at the top like obtuse cones; but in other respects they partly take the form of the containing cavity. The tops are joined to the windpipe; and the bottoms, by the arteries and veins, to the heart. The right lung consists of three lobes conjoined; and the left but of two, which is also excavated to make room for the heart. The colour of the lungs is, in infants, reddish; in adults, greyish; and in old age, blue or black. They are entirely composed, except the nerves, of blood and air vessels. The air filling them to all appearance almost as water is absorbed in sponge. Yet the air vessels are all complete channels and ramifications from the bronchea. Inside all these divisions are the arteries and veins, which are also ramifications leading from the right ventricle to the left auricle. It is found that an artery is always on one side of an air vessel, and a vein on the other.

The superfices of the internal surface of all the air vessels in the lungs, is supposed to be equal to the external surface of the whole body; and their capacity is such, as to hold at a gentle inspiration, about 42 cubic inches of air. Now about 1200 inspirations take place every hour, making on the whole 504,000 cubic inches to which, in the same space of time, all the blood in the body is fourteen times exposed, allowing nearly 3600 cubic inches for one circulation. At every inspiration, the oxygen of 1·56 cubic inches of gas is taken into the blood from the air. This will allow $134\frac{3}{7}$ cubic inches to one circulation or 45·7 grains by weight. As by this oxygen gas a continual combustion is kept up in the frame, so its products, viz. water and carbonic acid, are thrown out at every respiration. But though this interchange takes place, the air and blood are not mingled together: they are kept asunder by the membraneous coat of the blood vessels, through which the interchange is

made; and which is so delicately thin, that its nature or texture has not yet been ascertained.

But though we have the structure of the lungs and their office thus before us, we yet want the power to make them play. A bellows may be well made and complete in every respect, but is of no avail without the motive power. The motion of the lungs is as mechanical as that of any forge bellows, and the principles on which both act are exactly the same. It may be remarked, that though all the motions of the organs are muscular, yet some of them are independent of the will, and others nearly so;—for the exertion of them, as of the lungs, is so familiar that even in the soundest sleep we do not forget to ply them. The ribs, which form the cavity of the breast, called the thorax, are joined to the back bone; but not immoveably fixed. They are not placed at right angles to each side of it, but slope a little downwards. The uppermost rib being the shortest, of course the chest is narrow at the top and wide at the bottom. Before the ribs meet at the front they begin to turn or slant upwards, and are finally fixed to the breast bone. By means of muscles, these ribs and the breast bone, being all as it were one piece, are lifted up—the articulation to the back bone allowing a small play in this direction. Now the lungs being fastened on their external surface on all sides, and at the top and bottom; and the chest in which they are placed being separated from the abdominal regions by the diaphragm;—therefore when the breast bone is lifted upwards by the contraction, the lungs are extended on all sides; and a cavity is made inside of them, into which the air rushes by its own pressure and elasticity. And as its motion is simultaneous with the rising of the breast bone, the power exerted in the muscles is comparatively small. The distention of the cavity of the breast is about one-tenth of an inch in diameter; but this, with the internal cavity made by the contraction of the diaphragm, makes room for about 42 cubic inches of air; and in some persons, on occasions of extraordinary exertion, from 70 to 100 cubic inches are inhaled. By the descent of the breast bone, the air is expelled, and thus is the process of respiration carried on.

7. ORGANS FOR ASSIMILATING THE FOOD.

To understand the nature and office of these vessels, it is necessary to trace the progress of the food from the mouth to its entry into the blood, which it makes immediately before the blood enters the right auricle of the heart.

Before the food is taken up to be carried to the blood, it undergoes four processes. The first is when it enters the mouth, where it is masticated and mixed with the saliva. It is thence carried by the esophagus into the stomach, where the superfluous water is drained off, and it is then digested into a fine soft pulp, called *chyme*. It then enters the intestines; the first of which is the *duodenum*, a gut about 12 inches long, where it undergoes two other processes; for immediately after it enters this gut, it is acted on by the bile,—a peculiar juice secreted from the blood by the liver, and poured into the gut by a curiously contrived tube. The bile, containing soda in a caustic state, converts the chyme into a soapy substance, neutralizing the fat and making the whole of one consistency. Here then it has undergone the third process; but because it is now in an acrid state, and perhaps unfit to be hurried to the delicate vessels that convey it to the blood, therefore, another fluid is poured out of a tube a little further along the duodenum. This tube leads from the pancreatic gland, and the fluid called the pancreatic juice, is of a mild nature, fitted to correct and temper the sharp and caustic qualities of the bile. When the food, after these four previous preparations, has arrived at the intestinal canal, it may be considered as similar to the soil in which the roots of plants are placed, and from which they draw the sap. To perform this office in the animal, the intestinal canal is beset all round, and from end to end, though it is 12 or 13 yards in length, with myriads of little vessels called the *lacteals*. Therefore as the chyme passes along this winding canal, the lacteals are continually sucking up a fluid from it. This fluid is called the *chyle*; and the mouths of the vessels, that they may take nothing gross into the blood, are so small as not to be detected even with the microscope; and the vessels themselves can only be seen by the help of that instrument when they are distended with the fluid. These minute vessels soon unite together and form large branches, that terminate in glands from which still larger pipes proceed, till all the chyle

enters one common reservoir, called the receptaculum chyli, which holds about two table spoons full. From this a pipe or vessel called the *thoracic duct* proceeds; climbing up behind the chest along the esophagus, by which the food enters the stomach, till it reaches the neck, where it is emptied into the blood; and being churned in the heart, is hurried away to the lungs to be there elaborated.

All these ducts or vessels are furnished with muscles; and have a peculiar motion by which they are enabled to transmit their contents from one to another. After the food is masticated by the teeth, the muscles of deglutition, send it through the pharynx into the esophagus, whence by the muscular contraction of that duct, commencing at the top, it is forced down to the stomach, which it enters by the *cardia*. In the human esophagus those muscles are slight, by reason of the erect position of the body; but this is not the case with browsing animals, as with the horse and cow,—a strong muscular exertion being required while they have their heads down in the act of grazing. The stomach is a bag which, when distended, is capable of holding, in a moderate man, from three to three pints and a half. When well filled both ends are shut up; and the fuller it is, the more tightly are its orifices closed. It is much in the shape of the pouch of a Highland Bagpipe, lying transversely across the body. The orifice by which the food enters, is lower than that by which it passes out, so that it is forced through by a gentle undulatory motion, which commences at the cardia and ends at the pilorus; the progress is greatly assisted by the wrinkles of the inner coat of the stomach. The chyme is propelled slowly along the intestines by a peristaltic or vermicular kind of motion, so that by its slow progress, and the length of the passage, all parts are exposed to the mouths of the lacteals, which pump up the nourishing or finer parts, and the grosser are expelled. The lacteals are too small to ascertain by observation, in what manner the fluid is made to pass along them; and the thoracic duct, having no pulse to propel its contents which have to ascend, is furnished with a number of valves, that open upwards; so that the chyle is, as it were, caught step by step, and lifted up to the subclavian vein, where it enters, drop by drop, into the blood.

8. ABSORBENT OR LYMPHATIC SYSTEM.

BESIDES the arteries and veins, there is another system of vessels connected with the circulation of the blood. They are called *absorbents* from their supposed office of gathering up the effete particles, or such as have gone through the process of animalization. They also cleanse the system from internal pus, &c., hence they are sometimes called *detergents*. They are denominated *lymphatics*, from the appearance of the fluid which they contain: being a colourless lymph consisting chiefly of albumen.

They are regularly dispersed over all the body. Their mouths lying obliquely open on the outside of the middle coat of the skin, imbibe external applications &c., but they here terminate principally in the soft cavities. Leewenhoeck calculated the mouths of seven thousand millions on a square foot of the surface of the stomach; and they are equally numerous on several other parts of the body. Their main trunks generally accompany the large arteries, and some of them the veins; and those from the lower parts of the body empty themselves by three or four large trunks into the receptacle of the chyle or lower part of the thoracic duct, which in fact they seem to compose. Those of the upper part of the trunk are emptied into the higher part, nearer to where that duct is discharged into the left subclavian vein. And such as come from the right side of the neck, thorax, and right arm, terminate in the right subclavian vein. All of them are furnished with valves, and are supposed to have a muscular coat, that propels their fluid.

9. GLANDS.

THERE are no less than about 20 fluids separated from the blood, by means of certain organs called glands. All these fluids possess very different properties, both in taste, smell, colour, and consistency; and in many respects, are as unlike each other as possible. Among different species of animals, these secretions contain directly opposite properties, such as the most nutritious aliments, and the deadliest poisons; the sweetest perfumes, and the most fœtid odours.

The largest of the glands is the *liver* whose office is to secrete the *bile*. To the underside of this viscous is attached the gall

bladder, which is in the shape of a pear, and capable of holding two or three ounces. In this bladder the bile is supposed to be retained a certain time, that some of its aqueous parts may be evaporated, and that it may be rendered more caustic before it enters the duodenum. But while it is retained here, it is sometimes concreted into knots, which stop the passage; and the bile regurgitates into the liver, and again into the blood producing the jaundice. The composition of 800 parts of ox-bile was as follows: water 700, resin 43, saccharine matter 41, albumen 4, muriate of soda 3·2, sulphate of do. 0·8, phosphate of do. 2·0, phosphate of lime 1·2, oxide of iron 0·5.

The *pancreas*, or what is sometimes called *sweetbread*, is a gland somewhat in the shape of the tongue of a dog; the point is conjoined to the spleen, and the other end stretches towards the duodenum, to which it is attached by the pancreatic duct. The pancreas seems composed of a number of small glands, each of which has a little duct. These terminate in larger ones, which uniting, finally form the main duct. The fluid secreted is not unlike saliva.

The kidneys are two glands whose office is to separate the urine from the blood. They are in shape of kidney beans, having the concave part towards the large vein ascending to the right auricle, as well as towards the great artery extending from the left ventricle. They consist of three parts. The cortical or outer part is composed of numerous convolutions of small blood vessels, in which the chief secretion is carried on. The middle consists of larger vessels, being the place where those of the outer unite and discharge into a vascular substance which consists of multitudes of small tubes that terminate in the inner part. This part consists of ten or twelve papillæ, each having several small orifices, through which the urine drops into a small reservoir, whence it is conveyed from each kidney to the bladder, by the two vessels called the ureters.

The parotid glands, which secrete the saliva, lie between the ear and the lower jaw. A pipe about the thickness of a wheat straw, and about three-fourths of an inch in length conveys it to the mouth. The orifice of this tube is in the middle of the cheek. Saliva consists of 99·29 water ·29 peculiar animal matter, ·14 mucus, ·17 alkaline muriates, ·09 lactate of soda, ·02 pure soda.

The esophagus, stomach, and intestines all consist of four coats; one muscular and one glandular, which secretes its own

peculiar juice. This juice, in the esophagus prevents thirst, and lubricates the internal part of the intestines; but that of the stomach, called the gastic juice, has a much more important office, viz. that of digesting the food. It is a thin colourless liquor, exuding from the glandular coat of the stomach. The manner in which it acts defies the scrutiny of philosophy to discover. It is said to be, not by chemical affinity, and yet it will reduce the hardest and toughest substances that are usually conveyed into the stomach to a soft pulp. In some animals, as in the ostrich, it will dissolve even small bits of iron and hard pebbles. Yet this juice when taken from the stomach, is found to be as harmless and insipid as saliva or gum water, which it much resembles. Nor does it attack the coats of the stomach while life remains; except when the stomach is empty, it has been supposed to irritate the internal coat, and cause the gnawing pain of hunger. But in some cases of sudden death, where its power had not been injured by disease, it has been known to attack the stomach equally with its contents. And as the gastric glands and their powers must be adapted and proportioned to the quantity and quality of the food, so we find them the largest and most numerous in animals destined to inhabit the most barren regions of the earth, and in those whose supply of food is the most precarious; so that they can eat as much on one occasion when they can obtain it, as will serve them for a considerable time. In animals that continually live in abundance, they are much smaller; in man they are the smallest,—a wise provision against the luxurious pleasures of the table.

Besides the glands already mentioned there are many others, as those which separate the tears, and the oily mucilaginous matter that libricates the joints, also those in the female that secrete the milk, with many others.

10. THE INTERNAL PARTS OF THE BODY AND THEIR DISPOSITION.

The internal cavity of the body, made by the ribs, is divided into two compartments by the diaphragm. The upper is called the thorax or chest, and the lower the abdomen.

The *diaphragm* or midriff is a broad strong muscle; attached, behind, to the lumbar vertebræ or back bone; at the sides, to the ribs; and at the front, to the sternum. Thus it forms a complete division; the large blood vessels and the esophagus passing

through it. It is disposed like a vault over the abdomen, the convex side, being within the chest, diminishes its cavity, or makes the lungs collapse; but by the contraction of its muscular fibres, it is reduced to a flat ceiling, which enlarges the chest and dilates the lungs. And as this motion is simultaneous with the rising of the breast bone, as stated sec. 6, it appears that the diaphragm is a considerable auxiliary in the process of respiration. It is also a chief agent in the acts of coughing, sneezing, laughing, gaping, sighing, and some others belonging to the viscera of the abdomen, many of which could not perform their office without its assistance.

In the thorax are placed the organs, which by way of preeminence are styled the vital organs, viz. the heart and the lungs; the esophagús also passes through it. The cavity of the thorox is lined with a membrane of a firm texture, called the *pleura*. This membrane consists of two distinct bags, one placed on each side. Their design seems to be to contain the lungs, their adjoining sides therefore form a division of the thorax; and by being fastened to the sternum on the front, and attached to the vertebræ behind, form a stout partition wall, called the mediastinum, between the lungs. Many inconveniences are obviated by this partition, which particularly serves as a stay for the lungs, and prevents the lobes of the one from pressing upon those of the other,—when we lie on one side; and consequently it contributes to the freedom of respiration.

The heart and the great blood vessels are securely lodged in a strong membraneous bag called the *pericardium*. This sack is partly inserted between the two bags of the pleura,—they receding a little at the underside to make room for it. Its basis is strongly fixed to the mediastinum, and its point to the middle tendon of the diaphragm. The heart is placed almost transversely across the breast, the broad end or basis being directed to the right side, and the apex to the left, so as, when it beats, to strike the sixth rib. It is fastened to the pericardium, and farther sustained by the large blood vessels. All these bags, and in fact all the viscera, have their appropriate juices secreted, with which they are moistened and lubricated, so as to prevent friction or adhesion.

The abdomen is naturally divided into two parts by some of its viscera being included in a large bag called the peritoneum, which is a thin soft transparent membrane, yet strong and capable of being considerably extended. The viscera contained in

it are the stomach, the liver, the pancreas, the spleen, the omentum, the mysentery, with the lacteals and intestines.

The stomach is placed on the front at the top of the abdominal division of the trunk. It is laid transversely across the body rather inclining to the left side, at which side the esophagus enters. The external coat of the stomach seems an extension of the peritoneum; and, of course, is thereby fastened. The pancreas is placed behind the stomach, one end rather beneath the liver and the other joined to the spleen, The omentum is a membrane produced from the peritoneum doubling upon itself at its lowest part, like a tucked up apron. The upper edge is tied to the underside of the stomach, to the spleen, and part of the duodenum. The turned up edge, after forming the doubling, comes behind the front flap, and is joined to the colon and contiguous viscera. The omentum, containing a large quantity of fat, is supposed to perform the office of lubricating the intestines placed below.

The liver is placed immediately beneath the diaphragm, behind or rather to one side of the atomach. It consists of two lobes of unequal size, the larger one filling the right side, and the smaller extending towards the middle or front, is kept in its place by two ligaments. The one comes from the covering of the diaphragm and penetrates the substance of the liver; the other is the umbilical cord, which after birth becomes a ligament. The first preserves the liver in its position when we stand upright, walk, or leap; and must therefore be large and strong. The other prevents it pressing on the diaphragm, should we stand on our heads, or should the body by accident be inverted; and both together suspend it when we lie on our backs, and prevent it from pressing upon the large vein placed behind it, which returns all the blood from the lower parts of the body to the heart.

The spleen is a soft spongy substance of a colour between a dark red and blue. Its shape is extremely irregular, and it is confined to its place by adhesion to the peritoneum and diaphragm, and by a ligament to the omentum. It is extremely full of blood vessels, but has no visible duct. It has been removed from a living dog, and the animal still prospered, shewing no symptoms of his loss, so that its use is not yet satisfactorily ascertained. Some late experiments seem to prove that water passes from the cardiac part of the stomach, through the spleen and liver to the bladder; however the ves-

sels to, and through the spleen, are so minute that they have not yet been discovered. Some drinks have been ascertained to pass this way, and to have been voided in 17½ minutes. It is also supposed to have something to do with the colouring of the chyle; which, before it arrives at the thoracic duct, receives a red tinge;—but how it receives it, is not known.

The mesentery supports the intestines, and is itself fast tied to the first three vertebræ of the loins, or that part of the back bone immediately beneath the diaphragm. It is of a fat, suety nature, and of considerable breadth; and not only keeps the intestinal canal in proper order, but also contains the lacteals, which pervade nearly the whole extent; and in it are likewise placed the arteries and veins which supply the intestines.

The intestines are the whole of the alimentary canal reaching from the stomach to the rectum; and as it is above six times the length of the whole body, and crowded into a very small space, it is evident some very ingenious contrivance must be necessary to keep it in order; without which when the body is jerked, and tumbled in all possible ways, whether in dancing, running, or leaping, the many folds of this prolixity of gut must be in danger of being entangled. And as it is composed of materials, that are soft and pliant, their passage must needs be stopped. However this is obviated by the following contrivance, viz. the lower edge of the mesentery is a kind of face or broad edge to which the gut is fastened;—but in being fastened, it is puckered in as the frill of a shirt is gathered to the cloth, so that the gut is four times the length of the edge; or four inches of the gut are joined to one inch of the mesentery. By this kind of suture, it is capable of that peristaltic muscular motion, which propels the chyme along it. And the mesentery, being fast bound to the back, and its folds being regularly disposed, the intestinal canal is consequently arranged across the lower abdomen, without a possibility of its folds being entangled or of their interfering with each other.

The viscera of the abdomen, not placed within the peritoneum, are the kidneys, the ureters, the receptacle of the chyle, the aorta, and the vena cava ascendens. Yet the kidneys, ureters, and the upper part of the bladder are contained in a duplicature of the peritoneum; but by the main bag of that membrane, they are protected from the pressure of the other viscera. The upper or thick end of the bladder, is tied by the urachus to the navel; and the two ducts, called the ureters, form

a communication between it and the kidneys, which are safely lodged in a bed of fat.

Thus we see, how carefully all parts of the body are packed up and tied, so that there is no possibility of their derangement by the contortions, sudden jerks, and various shakings to which the whole is liable. They are also prevented from one pressing upon another, and impeding the motion of their respective fluids, or otherwise molesting each other's proper functions.

11. EXTERNAL PADDING AND COVERING.

THE bones form the support or prop-work of the animal superstructure; the muscles attached to them give it motion and proportional symmetry; to both are fastened various organs and viscera, which furnish materials for the support of the whole; we now only want external padding and leveling, and something strong and durable, not only to cover the whole, but to hide the internal parts from our sight. For were all the organs and their operations placed within our view, we should continually be in danger of being frightened to death with apprehension, lest the many thousand things on which life and comfort depend should not all go right.

There is therefore placed all over the muscles immediately under the skin, to which it seems to form a cushion, what is called the cellular or adipose membrane. It is a white membraneous substance or net work, full of cells almost like a sponge. Into these cells is poured the animal oil, and the whole taken together constitute that part of the flesh called fat. This extending all over the body, fills up the cavities of the muscles; hides or diminishes their protuberances, and smooths their asperities; and increasing, when its cells are well filled, the bulk of the body, stretches and gives sleekness to the skin, which, also from the oil beneath, is made soft and smooth:—hence, to the cellular membrane is owing, the roundness, and plumpness which are the distinguishing characteristics, and form the peculiar beauty of well fed animals.

The skin is the outward covering of the whole. Like the bark of trees, it consists of three coats; the external one is called the cuticle or epidermis, the middle one is the mucous membrane, and the innermost is the cutis. The first is a thin transparent membrane, very porous, and possessed of neither colour nor feeling: for it may be pared off without our per-

ceiving it. But immediately beneath it, and over the mucous membrane, are spread the extremities of the nerves. This middle coat is of a thin, soft texture, consisting of a mucous substance, whose colour somewhat varies in different persons, and stamps the character of fair and browh on the complexion: in negroes it is completely black. Europeans now wear artificial mucous membranes made of calico; and this, it is said, enables them to bear the heat of the torrid zone like a real black. The cutis is the thickest, toughest and most durable of the whole. It is this, which in animals is so useful in making leather; being, as well as the other two coats composed of gelatine, which combines with tannin.

The skin in places is semitransparent, and partly shews the veins and arteries through it, which latter give floridness to the complexion. But where the skin covers the bones or cartilages, there, the colour of these, viz. white, or bluish white, predominates. In other places, where the skin is thick, or least stretched, it is more opaque and only its own yellow hue is seen.

But besides the external beauty and substantial covering which the skin affords to the whole, it has another important office: for through it is a continual evacuation. Both nerves and arteries terminate beneath the epidermis, the latter of which are continually exuding a matter called perspiration. The absorbents have here also their mouths open to gather up external applications. But the mouths of both sets are so very small, that Leewenhoeck asserted that the mouths of 125,000 might be covered with a grain of sand. However the quantity of matter evaporated by perspiration is said to be more than equal to all other evacuations. But it differs in different persons, is more copious in youth than in age, during sleep than awake, depends a great deal on atmospheric temperature, and is greatly promoted by exercise. When it exists in such quantity as to be in drops, it is called sweat or *sensible* perspiration, at other times, it is denominated *insensible*. The matter perspired contains pure nitrogen, acetic acid, and perhaps an unctuous matter from the nerves: the basis is water.

12. BRAIN AND NERVES.

THOUGH we have mentioned all the principal mechanical parts of the animal superstructure, and shewn that motion is

given to the whole by certain muscular contractions; yet we want that power which is to communicate this motion to the muscles themselves; without which, all we have been describing would remain inert masses. The *Will* is the power by which this motion is generally directed, and the nerves are the channels along which it is conveyed from the Brain, the great *sensorium*, to that particular muscle which is to produce the desired action. The motary medium is the galvanic power, under the regulation of Life, whose origin we know nothing about, but whose agency compels us to acknowledge the continual interference of a superior and superintending POWER.

The nerves may be considered as an extension of the brain over all the body; therefore, to understand them rightly, we must commence with a description of the brain, which is the substance that fills the whole internal cavity of the skull. It is of a soft, white, pulpy nature, composed chiefly of water, which constitutes full three-quarters of its whole substance; the rest is principally albumen, with a little phosphate of lime, phosphate of soda, phosphate of ammonia, and sulphate of lime; but altogether these salts do not form more than a three-hundredth part of the whole brain. It receives about one-tenth part of the blood of the whole body, although only about a thirty-fifth part of the weight; and contains many curious contrivances either to prevent the blood from pressing with too much violence on any particular part, or to modify its motion. The proportion which it bears to the whole body was found by two eminent experimentalists to be, in different subjects, as follows:

Child 6 years old	22	Fox -	205	Goose -	360
Adult -	35	Field Mouse -	31	Cock -	25
Ourang Outang -	22	Beaver -	290	Duck -	257
Great Baboon -	104	Elephant -	500	Sparrow -	25
Sapajou with prehensil tail -	25	Ox -	750	Canary Bird -	14
Mole -	36	Horse -	700	Tortoise -	2240
		Ass -	254		

All that the cavity of the cranium contains is included under the general term, *brain;* but it has several compartments, each having a different denomination. The whole is surrounded by two principal coats. The outer one, called the dura mater, is a perfectly smooth, inelastic membrane, that sends off several processes, which divide the brain into many portions, and prevent the lobes from compressing each other. Its inner surface

is bedewed with a fine pellucid fluid, which separates it from the inner coat. This coat, called the pia mater, is a very delicate and transparent membrane, much softer and finer than the other. It is composed of two lamina: the outer one is a mere film and spreads uniformly over the whole brain; while the inner one insinuates itself between the convolutions, and even enters into the wrinkles and interior cavities. In it are ramifications of blood vessels, which send out small capillary tubes that perforate and supply the brain. The largest portion of the brain is called the *cerebrum*, or brain proper. It partly consists of six lobes; one each side the forehead; one each side the middle; and one each side the hinder part: these occupy the upper part of the skull filling the chief of the cavity. Beneath the two hind lobes is situated the *cerebellum*. A third part which connects both, and from which the nerves chiefly proceed, is called the *medulla oblongata*.

The cerebrum appears to be composed of two distinct substances, the exterior one is the softest part of the brain. It is of a greyish colour, in this respect resembling wood ashes; but the other is a very white medullary substance. The cerebellum is divided into two lobes. It differs in consistency very little from the cerebrum, though some suppose its texture to be finer. It is also composed of the same two substances, but the outer one is somewhat larger in proportion. The medulla oblongata is formed from the union of two chief ramifications; one from each inner substance. It is situated at about the middle of the under part of the brain, right over the vertebræ of the neck.—This is an outline of the brain; but the internal parts are too various to be particularized in our prescribed limits. Indeed to do them justice would require a whole volume. Taken as a piece of curious mechanism, they are full as indefinable as the ideas often elaborated therein; and the particular uses of each part of the one, are, according to the old school of philosophy which prides itself in confessing its ignorance on this point, as utterly inexplicable as the origin of the other: but according to the phrenologists, each division of the brain is an organ that has an intelligible use in the animal economy.

The medulla oblongata extends through a hole in the skull into the neck, and down the canal of the back bone to its lowest end. This extension is called the *medulla spinalis*, spinal marrow or pith of the back. The pia and dura mater also accom-

pany it. The latter is fastened to the os occipitis or bone of the skull that joins the top of the neck; and is attached to the spinal canal by a cellular membrane, but is more strongly attached where different nerves branch off. That the spinal marrow may not by its weight oppress the medulla oblongata, the pia mater is attached by a new membrane to the dura mater. The spinal marrow is externally of a whitish colour; but internally is somewhat darker, so that it seems as if the order of the substances of the brain was inverted.

The nerves are medullary chords differing from each other in size, colour, and consistency. There are 39 or 40 pairs of nerves. Three of them branching off from the cerebrum; and 6 from the cerebellum and medulla oblongata: and the rest are from the spinal marrow. 1. Those of the sense of smelling. 2. Those of sight. 3. Regulate the muscles of the eyes: these are from the cerebrum. 4. Called the *pathetic* nerves because they regulate certain muscles of the eyes, which are used in the expression of certain passions. 5. This pair separates into three branches: one to the eyelids and forehead, another to the upper teeth, and the third branch to the lower teeth. 6. These assist in drawing the eyeballs from the nose. 7. Form the seat of the sense of hearing. 8. This pair is called *par vagum*; because they perform a multitude of offices: branching off to the organs of the thorax, and abdomen, viz. the heart, stomach, &c. 9. These belong to the tongue, and perform the double office of taste and linguary motion: these six pairs are from the cerebellum and medulla oblongata. From the veterbræ of the neck 8 parts proceed. From the back 12. From the loins 5. And from the lower part 5 or 6, which are called the sacral nerves:—these 30 or 31 pairs are principally distributed to the external part of the trunk, and to the extremities.

Besides the above primary pairs, there is a secondary one, called the intercostal, or great sympathetic. Its origin is not very certain, but it seems to commence from filaments of the 5th and 6th pairs. Passing through the cranium with the carotid artery, it thence descends down each side of the back bone; and receives branches from all the nerves, forming many ganglions, and sending off an infinite number of branches to the viscera of the thorax and abdomen, where they make several plexus with the 8th pair. However some doubts have lately arisen whether this is in reality a nerve.

When the nerves leave the spinal marrow, they generally consist of two kinds of chords, which are as it were knotted at certain lengths; and from these knots, called ganglions, fresh branches are sent off. All the nerves, likewise, as they are distributed through the body, unite with each other at places, called plexus, from which branches are again distributed. They then spread themselves over the muscles, penetrate the glands, surround every vessel, and pierce the very interior of the bones. They cover the whole of the external surface of the body: being spread out like a thin net-work upon the middle coat of the skin; and so delicately fine is this film, that we cannot see it with the naked eye; yet so completely does it cover the body, that we cannot prick the skin in any one part, without at the same time perforating a nerve.

The spinal nerves, according to Mr. C. Bell, have a double origin, one set of their filaments proceeding from the anterior, and the other from the posterior part of the spinal column. And it has been discovered by this eminent anatomist, that if the anterior filaments are divided, the part to which the nerve is sent is deprived of *voluntary motion*; while the division of the posterior filaments destroys its *sensation*. Now there is some grounds for supposing that the anterior part of the column is more directly connected with the cerebrum, and the posterior with the cerebellum; and hence it is conjectured that these two parts are respectively the more immediate seats of the two faculties. For the most part, the organs of sense receive their nerves from the brain; and the muscles from the spinal marrow, while the viscera are generally supplied with nerves from the ganglions or the plexus. Those latter are connected with each other, and with other parts of the body in a variety of ways, so as to insure a communication with all parts of the body.

Mr. C. Bell also arranges all the nerves into two classes:—to the first of these he gives the title of symmetrical or original; and to the second of irregular or superadded. The first set consists of the *fifth* pair and all the spinal nerves: they resemble each other in the mode of their origin, and in the circumstance of their passing laterally to the two halves of the body, the two sides having no connexion with each other; and they are distributed to all the voluntary muscles.—The second set, which arise principally from the medulla oblongata, or the parts con-

tiguous to it, proceed in a very irregular manner to all the organs which are concerned either directly or indirectly in the functions of respiration: hence they may be called the respiratory nerves. They pass from one organ to another in the most irregular manner, connecting them together, crossing the symmetrical nerves, and uniting the two halves of the body. The parts to which they are distributed, are not under the control of the will, and they appear to be principally concerned in what may be styled simple nervous action, that is, in transmitting the nervous influence from one part to another, without exciting perceptions. A *third* set are the intellectual, differing from the above two, and are different in different animals.

CHAP. XX.

Animal Economy.

1. Animal Temperature. 2. The Production of Animal Heat. 3. Vital Air and Food. 4. Nutrition and Motion. 5. The Detergent System. 6. Effects of the Electricity of the Earth and Atmosphere upon the Animal Economy. 7. Theory of Physic. 8. The Senses. 9. The Will. 10. Conclusion.

1. ANIMAL TEMPERATURE.

Having explained the superstructure of the human frame, and the adaptation of various organs to perform certain operations in the animal economy, it now remains for us to shew how the whole are put in motion, so as to discharge the functions of life; and in this case, also, we shall find the same principles actuating the animal machine, which pervade and move the whole frame of Nature. Chemical affinity, or the electric energies are here likewise the cause of all motion, but it is a secondary one; and however inexplicable their laws in some instances may be, owing to their being under the unknown principle called Life, and that still more intangible one, *Soul*; yet, we can demonstrate, that as matter is the vehicle of electricity, so electricity is the vehicle of life and will; and perhaps, also, the residence of the soul.

How necessary heat is to the animal system is evident, from the body, as soon as death has taken possession becoming cold; and the effects of heat in some other cases of animalization, particularly that of hatching eggs, might be advanced as

proofs that life depends on a proper supply of it. This supply is obtained from a combination of oxygen gas, imbibed by the lungs, uniting with the hydrogen and carbon of the food taken in by the stomach. The quantity of caloric thus produced in twelve hours, in a healthy person, has been calculated to be equal, to what would be required to melt 100 lbs. of ice. Now this heat is continually radiating from the body as fast as it is generated. The corporeal materials, indeed retain it so long as to produce a certain temperature; but when the calorific process is accelerated, the heat radiates more rapidly: the bodily temperature continuing very near the same. This temperature is about 96 or 98 degrees. In the coldest climates it scarcely ever descends below 95; and in the hottest is never above 100: though in a fever it is sometimes as high as 104 or 105 degrees.

The different sensations of cold and heat that we feel depend principally on the temperature of the atmosphere. In hot climates the atmospheric temperature, is sometimes equal to or above that of the blood; and, of course, the radiation of heat must be very slow, and the body oppressed. On the contrary the atmospheric temperature in cold climates is such, that were we not defended from the cold, or rather were we not by clothing to prevent the too great radiation of heat, it would escape faster than it is generated in the body, and the vital spark would be extinguished. In this is a wonderful provision of Nature: man being endowed with reason can protect himself against the cold, or can produce heat by other means than by the natural process in his body. He has not the same means of producing cold; and therefore is provided, independently of his own exertion, with an evaporating fluid; so that his body, when it would be at a temperature uncongenial with life, is relieved by perspiration, which is always in proportion to the caloric generated. A person in a fever does not perspire, which is the cause of the excessive heat.

All animals have a circulation of blood, and live by imbibing oxygen gas; though all have not a heart and lungs: so that in some, the quantity of oxygen consumed, is so little that it does not even colour the blood; their flesh is consequently white, and their temperature is little above the medium in which they exist—they are on this account distinguished by the term "cold blooded animals." Among these are most of the fish tribes; certain amphibious animals, and many reptiles that live principally in holes of the earth. That fish live by imbibing

oxygen, which they extract from the air contained in the water, is easily proved; for, if a fish is put into water that has been boiled, or has had the air expelled by heat, it is immediately suffocated. The same is equally the case if it be enclosed in a vessel of water that has not a free access of air, as in a well corked bottle; for as soon as the air of the water is exhausted the fish dies. They have also the means of decomposing both air and water. A fish was kept in a vessel of distilled water for three years; and fed all that time with distilled water, when it at last grew too large for the vessel.

Cold blooded animals are capable of enduring a much lower temperature than the warm blooded. Even a frog, whose blood contains a considerable quantity of red particles, has been frozen till it chipped like ice, and yet by careful thawing was restored to life. Whales are hot blooded animals, having nostrils or blow holes, and come to the surface at stated intervals, when they first expire a large quantity of carbonic acid, aqueous vapour, and the refuse nitrogen gas; and then inspire a store of atmospheric air, with which they descend to the bottom of the ocean, till all the oxygen gas is exhausted, when they again ascend for a fresh supply. Birds in proportion consume more oxygen gas than man; and they have therefore a much higher temperature, which is 103 or 104 degrees. The temperature of all animals is in proportion to the air which they breathe; and the greater the proportional quantity of air breathed, the greater is their muscular strength.

2. PRODUCTION OF ANIMAL HEAT.

The economy of animal heat is somewhat similar to that of vegetable heat; though the immediate sources are very different. In the latter, the sun and atmosphere furnish the positive electric fluid, and the earth the negative; so that the operation of the plant is that of replacing the electric fluids in the respective elements:—but in the former, the electric fluids are separated from their respective elements; the brain some how or other becomes charged with the positive fluid from the carbon and hydrogen taken in as food by the stomach, while the blood is charged with the negative contained in the oxygen imbibed by the lungs. The brain branches off in nerves over all the body, and these ramifications become so attenuated that not a particle of matter exists in the body which is not in contact, either with

a large branch or some of the network of the nerves:—in like manner the arterial blood loses itself in millions of invisibly small tubes called nutrients; and as the oxygen imbibed by the lungs is carried along with it by means of the red or colouring particles with which it unites, as is also the chyle recently taken in by the food; the blood is in these nutrients met by the positive electricity of the nerves, and here is the animalization carried on. By the inscrutable laws of life, the worn or otherwise injured parts are repaired with the new materials; the absorbents take away the effete or refuse particles, and the small veins gather up the blood: but as a continual combustion is going on by the union of the carbon and hydrogen with the oxygen of the blood, that expends a great deal of this, independent of that which goes to repair and increase the frame, so a proportional quantity of carbonic acid and water is also produced which is taken away with the blood. Therefore when the blood comes to the lungs again, carbonic acid and aqueous vapour are given out, but principally the former; the latter being mostly secreted by the glands which it passes through before it reaches the lungs.

When the blood has taken in the supply of oxygen in the lungs, its colour is a bright red; and the arteries along which it is conveyed are a lively pink. But when by ignition it has parted with the oxygen, and is taken up by the veins, it is reduced to a dark bluish red, which is the cause of the blue colour observed in the veins. Venous blood when exposed to the air, imbibes oxygen: its surface assuming a bright red pink. Should a little be put in a bottle and closely corked, the same effect will ensue; and the air in the remaining part of the bottle, when examined will be found to have lost its oxygen. But since the oxygen cannot combine with the red particles of the blood without some caloric being produced, it has been ascertained that by this means the arterial blood attains one degree of temperature. Carbonic acid has a much less capacity for caloric than the other materials of the blood; and nitrogen gas has even less than ice itself;—a wonderful contrivance for preventing the dissipation of vital heat by respiration.

How the brain is supplied with positive electricity is not yet clearly demonstrated, but from the great sympathy existing between it and the stomach, it seems to have its supply from the digesting food. Several arguments might be advanced in support of this hypothesis, particularly the rapidity with which

alcohol, or the still more inflammable fluid, *ether*, when taken into the stomach, affects the brain. It is well known that these are the most inflammable of all substances, that usually enter into the stomach, being carbon and hydrogen, in which the combustion may be said to be commenced by the small quantity of oxygen with which they are in alcohol and ether combined. Our induction is, that as the food, or at least the nourishing part of it, is chiefly carbon and hydrogen, when operated on by the gastric juice, it parts with some of the positive fluid which ascends to the brain along the vast ramifications of nerves that embrace and perforate the coats of the stomach. Hence that rapid action of the gastric juice, sometimes called the chemical wonder; and that languor or lowness of spirits which is felt when the stomach has been any length of time empty; also that revivification on taking a little food, or more quickly so on taking a glass of cordials, which in all cases owe their virtue to the presence of alcohol. This enlivening effect is found long before such substance can be assimilated, or conveyed by the lacteals into the blood.

The gastric juice, by reason of the impossibility of taking it from the stomach unblended with other substances, has never been analyzed. However it has been ascertained, that in animals feeding on grass it is slightly alkaline; in animals of prey, it is slightly acid; but in man when healthy, it is neither. The saliva, whose composition we have already stated, in its sensible properties differs nothing from the gastric juice, and being well mixed with the food in the process of mastication, greatly facilitates digestion, probably by bringing the gastric juice into more immediate contact with the elementary particles of the food. Now the gastric juice does not blend promiscuously with the food in the stomach as we must suppose the saliva does, but only performs its wonderful office by being in immediate contact with the nerves and the very external elementary particles of the food: for only a very thin coat of food next the lining of the stomach is digested; which is then pushed forward and another coat is presented, which in its turn is also pushed forward. In examining the stomachs of animals that have recently taken food, the new food is never mixed with the old, but forms as it were a central part, so that it may be withdrawn from the centre leaving the old as lining round the internal part of the stomach. The stomach is also incapable of digesting food diluted with too much water, whe-

ther that water forms the basis of soups, ale, wine, or any other beverage, which must all be removed before the digestion proceeds, so that the digested food always passes out of the stomach with the consistency of a thick paste, whatever the quantity of drink taken. Now as the gastric juice when taken out of the stomach is as inert as the saliva itself; its peculiar energy must be owing to life, or rather to the attraction of the nerves for the electric fluid.

But though the saliva is thus inert when taken from the mouth, or merely as it remains mixed with the food in it; yet, we are not assured that it is altogether destitute of all the dissolving properties of the gastric juice; it seems to be the assisting medium of taste. The seat of taste is centred in the tongue; but rub the tongue dry, and place a moist substance upon it; and we shall have a feeling, but a very imperfect sense of taste. Indeed, were it carefully examined it might perhaps be found, that when there has been the sensation called taste, there has been the intervention of saliva. The internal chords of the nerves are always moist; and it is here supposed that the office of the saliva is to increase the moisture by forming a communication between the electric energies of the substance tasted, and the nerve, and consequently with the brain: and we suppose the gastric juice to form a similar office; viz. by its agency or intervention, the inherent positive fluid of the food is drawn off to supply the brain. Should this be the case, which seems not very improbable, then this chemical wonder of the gastric juice will be done away, or will rather be transferred to the nerves, since it is only a continuation of the electric chain, or forms a conductor between the inherent electric fluid of the food and the nerves: blending with the external elementary particles of the food, and touching the moisture of the nerves, that communicate with the brain and by sympathy with the whole body. When these nerves directly communicating with the stomach are divided or cut, the digestion ceases, or the gastric juice is no longer liberated.

A further proof that the brain is concerned in the production of heat, is, that if the principal nerve, which supplies a limb, be cut or compressed, that limb becomes cold, and the blood retains its oxygen after it has circulated through the limb just as when it flowed along the arteries. The limb becomes equally cold when an artery is stopped. Many cruel experiments have been tried on animals, to prove whether the action of the heart

and lungs depends on the energies of the brain. When the head is totally severed they immediately cease; but by an artificial motion of the lungs, the motion of the heart will continue for some time; however it has been duly ascertained that, in this case, no heat is evolved. As the nerves are all connected with each other independently of the brain, so when the pith is severed at the neck, the communications being formed by the nine pairs that proceed immediately from the brain or medulla oblongata, various appearances take place in the body of the animal: hence no two experimentalists have exactly agreed in their results, and such experiments have therefore, been unsatisfactory.

Owing to this great sympathy existing in the nervous system, some compounds affect the brain almost miraculously. The essential oil of bitter almonds, of laurel and tobacco applied to any part where they can come immediately upon the nerves, as upon the tongue, cause instant death. Even a concentrated infusion of tobacco injected into the rectum will cause syncope. These act therefore without their coming into the circulation, and prove the electric nature of the nerves. In like manner these substances have the property of stopping fermentation, so that their effect as well as that of all other poisonous vegetable substances, when taken into the stomach is evidently that of causing an immediate cessation of the liberation, transmission and combination of the electric fluids. Some of the poisonous animal and mineral substances appear to cause a decomposition of the blood, and must therefore enter the circulation; even atmospheric air seems to have the same effect, for a small quantity ejected into the jugular vein of a dog or horse will almost immediately kill him. Some of the oxides perhaps owe their deadly efficacy to their decomposition, when the oxygen merely quits its base to combine with the carbon and hydrogen of the animal fibre.

As both arteries and nerves terminate at the skin, electricity is often, especially when the clothes worn are suitable conductors, exhibited around the human body. Any one putting off silk stockings in the dark will be sensible of this, especially if he should wear a pair of black ones over a pair of white, for they will adhere together; and if suddenly drawn off the leg or pulled asunder, there will be flashes of light. Several animals as the cat or horse, when smartly rubbed in the dark, will emit sparks: and some people, as mentioned in the Ency-

clopedia Metropolitana, have been endowed with this very peculiar property to a wonderful degree. Certain fish, as the torpedo, the gymnotus, and silurus electricus, are endued by nature with the voluntary power of exciting electricity. Should a person touch the back and belly of the torpedo with each hand at the same time, he will feel a very benumbing shock, but more so should the fish be touched with the finger and thumb of the same hand; and the shock is four times stronger when the experiment is made in the air than in the water. The gymnotus electricus is peculiar to Surinam: it is sometimes upwards of twenty feet in length, and its shock is often instantaneously fatal. These fish are furnished with a distinct set of organs for the liberation of the electric fluids; and have a much greater proportion of nerves principally connected with the electric apparatus, than any other animal. The apparatus is double: one ranging down each side of the fish; and the nerves on each side consist of three branches, proceeding from the hinder part of the brain. The arteries pass immediately from the lungs to the electric organs, the main trunk accompanying the main branch of the nerve, and the blood thence returns by veins to the auricle of the heart: the ramifications of the nerves and arteries are curiously radiated for the retention of the charge. The least injury done to the brain of the torpedo destroys its power of giving shocks; and it is said that a person does not suffer from its shock if he holds his breath.

3. VITAL AIR AND FOOD.

THE capability of the blood for conveying the negative fluid or oxygen depends upon the red particles which it contains; but the quantity of these varies in different persons, and at different times in the same person. When they are comparatively few and the blood is pale, the temperature is low and the muscular exertion is feeble; but in men of robust constitutions, the red particles abound, the quantity of oxygen consumed is great, the fire in the frame is proportional, and such men scarcely know their own strength. But as animal heat altogether depends upon the supply of the negative fluid taken in by the lungs, being balanced by the positive taken in by the food, it is evident that this balance must be considerably affected by the quantity and quality of the food.

Now food, by which is meant such substances taken into the

stomach as principally consist of the elements found in the animal system, and these slightly combined with oxygen, is of various kinds; but may generally be arranged under three divisions, viz. the heating, the nutritive, and the cooling. Under the first will be ranged animal food, and all drinks containing alcohol: being such as contain either the smallest quantity of oxygen, or have already been subject to the process of animalization. The second will include the vegetable substances gluten, starch and mucilage; and the cooling will consist of saccharine matter, or the pulp of fruits or watery vegetables.

Of the animal substances, fibrine, gelatine, and albumen, there is no striking difference in their composition; only fibrine contains the least oxygen, and may be converted by more oxygen or by being digested by sulphuric acid, either into gelatine or what very much resembles it; and albumen when once coagulated is insoluable, so that it might be concluded from this, as is proved by experiments on the white of eggs, that it is not very nutritious. But here we have the intervention of another simple substance, viz. nitrogen. We have already stated, that nitrogen "is considered as the element which nature employs in converting vegetable into animal substances." Now nitrogen is scarcely any where found in vegetable substances except in gluten, which is small in proportional quantity to starch, mucilage, and saccharine matter; and is not found at all in some herbs on which animals are entirely fed whose flesh contains the usual quantity of it; in such animals therefore it must either be formed in the animalization, or be obtained from the atmosphere and combined with the carbon, hydrogen, and oxygen in that process. However this may be, to its presence in animal food, is owing its highly nutritious or heating quality; for being already assimilated, it is ready to be deposited in the living fibre.

The second kind of food is the nutritive, not that it is more so than the first, but because it is less heating. Now gluten, as taken in different plants, we have already stated, almost graduates into gelatine; it therefore belongs as much to the first as to the second kind of food; consequently starch, mucilage, and what is nourishing in saccharine matter are properly included in this kind. These contain no nitrogen; but as animals, even man can live upon them; and attain though not to the first class, yet to a certain degree of muscular strength,

nitrogen must in the animalization be formed from or combined with the other elements. Now, though a man may not attain that vigour of body, by feeding wholly on these, that he will when combining with them a certain portion of the animal substances fibrine, gelatine, and albumen; yet, he would in all probability attain greater longevity by feeding on the three vegetable substances alone, than by feeding on the three animal substances alone. It seems very clear, both from analogy and observation, that the living animal fibre, formed from animal food, is more apt, having undergone the process of animalization twice, than that which is formed from vegetable food, which has only once been animalized, to run into putrescency. In short the one may be considered as new, the other as old. Hence, vegetable food is more conducive to health than animal food; but animal food is the source of strength, when great muscular exertion is required. Vegetable food may be called the proper food of inactivity, while animal food is that of exertion: a due mixture of both is therefore to be aimed at by those who would combine a certain portion of activity with health and strength.

The fat of animals, or oil whether animal or vegetable, when pure, contains neither nitrogen nor oxygen; and on it when alone the gastric juice seems to have no effect, for the stomach immediately ejects it either upwards or downwards without digestion; so that it appears a little oxygen under some form or other is necessary as an auxiliary to the gastric juice. But oxygen is charged with the negative electric fluid, and does not combine with the positive elements without their evolving some of their inherent charge: such food therefore as contains much oxygen, will supply but little positive fluid to the brain, not only because it contains less, but also because the oxygen retains some, or has a contrary effect; the fire in the frame will therefore be considerably less, and such food must be comparatively *cooling*. In this kind of food we place the pulp or pericarp of fruit, and certain other juicy vegetable substances, as well as sugar,—all containing a large portion of oxygen. Such food evolving little heat is consequently eagerly sought after in warm climates; and here the Creator, ever mindful of the wants of his creatures, has bestowed them with an unsparing hand.

Highly acidified substances must have a very peculiar effect when taken into the stomach. Should the oxygen be above a certain concentration, it must even attack the gastric juice itself, and exhaust the nerves: hence the deadly effect of

oxalic acid when taken in large quantities, although its bases are carbon and hydrogen. Vinegar also sometimes taken to prevent corpulency must do it at the expence of the constitution, for it must not only injure the gastric juice, but deteriorate the whole mass of blood. However to some people who eat rather for amusement than to support nature, vinegar may be of essential service: it occasions less electricity to ascend to the brain; consequently eases the head of the stupidifying dulness, and often acute pain attending overcharged nerves; and with very fat aliments, as pork, it greatly assists the gastric juice to perform its office in reducing to chyme what the stomach would otherwise eject undigested; so that, in moderate quantity, as in the state of pickles, vinegar is no enemy either to repletion or digestion; and a good draught of it is accounted the best antidote against an overdose of alcohol. Could the gastric juice have digested oil as rapidly as it does alcohol, not only man but carniverous animals might have been subject to continual intoxication: that it is not so, is a wise precaution of nature.

Water is a neutral substance in animalization, its elements having parted with the chief of their electric fluids; and though fish seem to have the power of decomposing it, yet in the human system it must be considered as acting more by way of menstruum, than as of itself imparting heat. All the fluids and secretions contain a considerable quantity, sometimes more than 99 per cent. of water, so that it seems to perform the same office in the whole frame that the gastric juice performs in the stomach; viz. it is the universal solvent, and maintains the continuity between the inherent electric fluids of each secretion and the nerves. Hence it is absolutely necessary in the animal economy, although it passes through the system undecomposed.

As food is diminished in strength by its union with oxygen or acids, so is the power of vital air destroyed by its combination with hydrogen and carbon; that is the air we breathe is so much the inferior by how much the more vapour and carbonic acid it contains. In large cities where much of this gas is generated, the air is in warm weather much contaminated with it. For being heavier than atmospheric air, it abounds the most near the surface of the earth; and, of course, occupies cellars, dungeons, and such like places. The inhabitants therefore of such situations can only have a scanty supply of pure vital air, and their blood must be in proportion destitute of

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oxygen, hence their pale visages and ghastly appearance. For the same reason a town standing on the banks of a river must be more favourable to health than one differently situated, since the carbonic acid will seek the surface of the water as being the lowest level, and it will thus glide away with the current. And as vegetables renovate the vital principles of the air, the superior salubrity of rural situations is very evident; as well as the utility to those, whose circumstances will allow, of retiring at the approach of night from the effete air of crowded cities, to the vivifying atmosphere of their country residence.

4. NUTRITION AND MOTION.

Though we have hitherto spoken of the blood as a mere heterogeneous mass of fluid, yet it is not destitute of a kind of organization. This consists of small cylindrical red globules, with colourless centres. In mammalia these globules are spherical, in birds they are elliptical, and vary only in the length of the greater axis. The colourless globule which exists in the centre has the constant diameter of $\frac{1}{300}$ part of an inch in all animals, and whatever be the form of the globule that contains it. The diameter of the globule in man is $\frac{1}{3750}$ of an inch in most other animals it is less. The globules may be considered as in the form of small perforated beads; and they float in the arteries parallel with the axis of perforation. When a wounded part is to be repaired, a globule comes to the surface of the sound part, and arranges itself at the end of the nutrient, and there extends its internal diameter and deposits its matter, thus lengthening the small tube of the nutrient; another globule comes inside of that, and is deposited in like manner, till the part is rebuilt:—so far has the process of animalization been discovered. In the smallest of the nutrients, only the internal colourless globule can pass, so that these vessels contain blood without red particles.

But when more carbon and hydrogen enters the blood by the agency of the stomach and lacteals than can be converted by their combination with nitrogen and oxygen into the animal substances fibrine, gelatine, and albumen, they are thrown aside by the blood into corners, being deposited as oil in the adipose membrane. Again, when the stomach is not supplied with food, this oil is taken up by the absorbents and poured into the blood, when it answers the same purpose as chyle or food: fat is

therefore so much food in store. Bears, in winter, live on their grease. They retire in the autumn bloated with fat into their dens, and sleep throughout the winter; but as respiration all the while goes on, there is an expenditure of animal substance—the elements must combine for the formation of caloric; and of course water and carbonic acid must be formed by the carbon and hydrogen of the bear's grease combining with the oxygen breathed: hence in the spring when these and other dormant animals have expended their store of oil, they are roused by hunger, and come forth lean and emaciated. Should they be roused by the exhausted state of their bodies, before the winter is gone, they frequently perish.

We have already stated the hypothesis, that the brain is supplied with positive fluid from the digesting food of the stomach, and have also suggested that life seems to impose new laws on the electric energies. It is a well known fact that the lacteals take up only such part of the food as is well digested; the chyle, then, must be considered as a peculiar substance containing less than its natural share of the positive fluid. We have likewise stated that when the oxygen enters the blood at the lungs, it does not there combine with the carbon and hydrogen, but only with the red particles of the blood, which are supposed to consist of phosphate of iron, so that the formation of water and carbonic acid is in the nutrients as described at Sec. 2. Nitrogen also somehow enters the system either by immediate formation or absorption, but where it is first combined with the carbon, hydrogen, and oxygen, whether in the stomach, in the blood or nutrients, is not yet discovered; till this is ascertained, we may in vain look for a satisfactory demonstration of the process of digestion.

The nerves act on the muscles or put them in motion by the positive electricity causing them to contract. This may be easily proved by electrifying the nerve belonging to the muscle of a dead limb; and even the fibrine in the blood will contract when touched with the positive fluid. A number of such contractions and relaxations, or counter-contractions, constitutes animal motion. But a muscle can neither be made to contract, nor can heat be produced without their being some oxygen to convey the negative fluid with which the positive of the nerves must unite. Consequently, independently of the fibrine and gelatine of the muscle necessary for the pull, it is almost as thickly beset with red particles as the blood itself, and there-

fore each muscle like the blood in the lungs must have its continual supply of oxygen. But by each individual contraction, that supply must be in some measure exhausted: hence the continual necessity of the rapid circulation of the blood, and the instantaneous cessation of motion when the supply is cut off by tying up the supplying artery.

Now every time the muscle is made to contract, the electricity of the nerves causes a combination of some carbon and hydrogen either of the blood, or more probably of the muscular fibre with the oxygen of the red particles, for carbonic acid and water with a corrèsponding portion of caloric are produced. Though this combination is continually going on, by reason of the muscular motion of the vital organs, even when the body is at rest; yet, when it is in motion the combustive process is much more rapid, and when nearly all the muscles of the body are in violent action the heat is found to be in proportion, and the consumption of oxygen must be so too. Whence then is the supply? From the lungs:—for we always find breathing to keep pace with muscular exertion. In violent exertion, such as that of running, a sufficient quantity of oxygen or air cannot be had; though the inspirations become more rapid, and the quantity inhaled each time is double that taken in while the body is at rest; yet, this kind of exertion is soon stopped for want of breath. And so much are the muscles working the lungs exhausted, that when we stop we can only pant, they having not a sufficient quantity of oxygen in the fibres to produce a full stroke. It is therefore a considerable time before the muscles of the limbs are recruited, or as we term it, before we gather strength.

As the consumption of oxygen is greatly increased by muscular exertion, so must an increase in the quantity of the positive fluid be required. Accordingly we find that exercise requires an increase of the quantity of food taken in by the stomach: for if the supply is not kept up here, the exertion will cease, the body will lose its heat, the action of the lungs will diminish less oxygen being needed, till, finally the nerves are exhausted, the lungs cease and the vital fire is extinguished.

Hence it it is evident that according to the muscular exertion must be the quantity of the two electricities to unite; and that too much food without exercise, or too much exercise without food, must cause an injurious superabundance of the one or the other electric fluid.

Should a person, whose blood abounds with red particles, and who, of course, retains a superior proportion of oxygen in his muscles, take a large dose of alcohol, the nerves will pour such a charge of positive fluid upon the oxygen of the blood, that the delicate vessels will not be able to endure the heat produced. They will be partly decomposed, and what is termed an inflammatory fever, may ensue; or the blood being impelled faster than usual, especially around the brain where the positive fluid most abounds, will frequently burst the veins, whose contents, being poured into the cavity of the skull, press upon the brain and stop its electric functions, when the patient is carried off by an apoplectic fit. But in less desperate cases, where there is no great excess of red particles in the blood, as with the habitual drunkard, the whole nervous system is injured by repeated overcharges. The gastric juice is not so much needed; its secretions not only become less, but its glandular organs are impaired; and therefore the stomach when free from the stimulation of alcohol, is unable to perform its office; the nerves, in consequence, instead of having more than enough for their purpose have not a sufficiency: and all the vessels of the system having become rigid and contracted by too much heat, are only able to convey their fluids when they have their accustomed high temperature. Under such circumstances, the feelings of the man who has innured himself to repeated doses of alcohol must be horrid, and a dram the only relief. But as the ill effects are every day increasing, he must every day have a larger dose to make his feelings less intolerable, till local inflammation of some organ, cuts short his days.

However, constitutions widely differ. The nerves of some being, as it were, in a state of explosion by a dose of alcohol; while the developement of the electric fluids are so sluggish in others, that the same quantity serves only to put them in a right state of mind. When it consumes the one with an internal fire, it but produces an accumulation of matter in the other. Hence some, with an excess of food, will take a large quantity of alcohol also; which seems to have no other effect than to hasten the circulation and promote the secretions. Such persons may continue healthy for some time, but as bodily decay or the feebleness of old age is caused by a rigidity or callosity of the vascular system, and an aridity of the nerves, such stimulating diet greatly accelerates these events; and therefore, he who indulges in them, greatly curtails the period of life. It is

remarked of all those who have been the most distinguished for longevity, that they always lived chiefly upon food of the cooling kind, that their regimen was such as would yield a moderate and even supply to the nerves, and that thoy were always remarkable for avoiding excess.

5. THE DETERGENT SYSTEM.

As animalization is carried on by the union of the electric fluids, and the combination of the elementary principles oxygen, carbon, and hydrogen, there must be by this continual ignition the products of combustion; which having parted with certain definite proportions of their electric fluids, are become effete; such as carbonic acid, and aqueous vapour, which are thrown off by the lungs, and a number of acids, salts and other ingredients, which are separated from the blood by the glands.

The liver seems to be the great cleanser of the animal system, for all the blood in its return from the lower parts of the body passes through it in its way to the heart. When the body is in a healthy state, the bile or substance secreted is made by the all-wise Designer serviceable to the assimilation of the chyle, but it is not supposed to re-enter the system. When by an improper diet or some other derangement of the system, the blood contains more carbon and hydrogen than can be disposed of in the adipose membrane, it is secreted by the liver: being converted into bile which contains a resinous substance supposed to be composed of this extraneous matter and the red particles of the blood combined with oxygen: hence those who are intemperate in diet are the most subject to bilious complaints.

However the kidneys, next to perspiration, as to quantity, secrete by far the most. Their office is to separate the superabundant water, which is charged with various ingredients, as muriate of soda, phosphate of lime, pus, acetic acid, and several other substances found in the urine; but all effete or principally such as are saturated with oxygen; and, of course, have performed their office in the system. It is found that the kidneys and the skin discharge nearly the same functions; and an excess in the secretions of the one, is always balanced by a deficiency in the quantity of the other. These substances are principally gathered from the system by the absorbents, and are by them poured into the venous blood. The absorbents

also cleanse the body from internal pus, occasioned by tumours bursting and discharging their contents internally. This they gradually gather up and convey to the thoracic duct, and it is afterwards evacuated by the office of the kidneys: if not properly cleansed from the blood, it is said to produce the hectic fever. That they perform the office of cleansing the skin, and conveying the substances to the blood, may be easily proved by rubbing the skin with a highly odoriferous substance, as garlic, which will shortly infect the breath.

It is very evident then that the absorbents perform a very important office in the animal economy; and being filled with a fluid which contains albumen, whose nature is very coagulable, on their derangement must depend some of the most inveterate diseases that can afflict the human frame. When the absorbent system is delicate or defective, it constitutes the disease known by the name of scrofula or king's-evil, which is sometimes transmitted from one generation to another. At times the lymph accumulates, and induces the large tumours we frequently see in persons afflicted therewith. But when the absorbents of any particular part are disordered which sometimes takes place, even in a person free from the hereditary taint, in extreme cases it terminates in the *cancer*. The glands, of which multitudes are disposed for various purposes in different parts of the body, are the most subject to this disease; not only because the fluids they secrete are not always entirely emptied from their vessels, but because the solid part of the gland is more compact in fibre; and, therefore, besides the absorbents having more to do, their work is the more difficult to perform. When the absorbents are injured by sprains, bruises or other causes in the joints, the enlargement occasioned by the accumulation of the lymph is called the *white-swelling*. When the scrofulous tumour is in the lungs, it is the *pulmonary consumption*. In short, wherever tumours rise gradually, whether in the bones or less solid parts of the body, they generally have their origin in the absorbents of that place not duly performing their office in gathering up the effete particles.

Now as repletion overcharges both the nerves and the vessels of the alimentary system, and indolence causes a stagnation in them; while, on the contrary, violent exertion promotes digestion or the developement of the electric fluids in the stomach for the supply of the nerves, and puts all the secretions of the body in rapid motion; and as diseases are induced by overcharged

nerves, and the different humours and secretions remaining too long in their respective channels:—it will hence appear how very necessary temperance and moderate, but regular exercise, are to the preservation of health. By temperance the blood receives no more carbon and hydrogen than can be well disposed of in the system, and bilious complaints are avoided; and by discharging the accumulated fluid of a full diet from the nerves, and by emptying the various glands of their respective secretions, not only scrofulous complaints, but a number of diseases, aches, and pains are obviated:—the muscles retain their full tone, the bloom of well oxygenated blood radiates the countenance, and a clear intellect directs the will.

6. EFFECTS OF THE ELECTRICITY OF THE EARTH AND ATMOSPHERE UPON THE ANIMAL ECONOMY.

We have stated Chap. XVI. that the earth's surface is generally charged negative, and that the upper regions of the atmosphere are always positive: but that the quantity and quality contained in the air at the earth's surface are often varying, and are different in different places, as on hills and in swamps or marshes; and that at times the earth is in a kind of morbid state, when its electricity is not extricated till a considerable portion of the globe is highly charged, and an earthquake ensues. Now as man stands upon the earth and moves in the air, his body must be charged along with them; and as the animal machine is put in motion by the electric energies, we must expect that a superabundance of the one or the other of the electric fluids must interfere with the movements of this machine. An overcharge of the positive fluid may cause the oxygenized red particles of the blood to combine with its carbon and hydrogen, before they reach the nutrients, when a quantity of matter must be thrown off by the liver under the form of the cholera morbus, or the black vomit of the yellow fever. Or by overcharging the nerves, too much heat may be occasioned, which may coagulate the albumen of the frame, or dissolve what nature requires to be kept firm, and thus introduce putrescency into the system. A too great prevalence, or an overcharge of the negative fluid may exhaust the body of its proper charge of the positive fluid and debility of the nervous system must ensue—and originate some formidable disease peculiar thereto, but varied according to circumstances.

Accordingly we find certain maladies corresponding to all the peculiar modes in which the negative fluid prevails; as rheumatism, nervous debility, head aches, and a multitude of pains, wit the intermittent and remittent fevers; also the typhus, the putrid, the camp, gaol, malignant, pestilential, and spotted fever; and, lastly the plague itself, all originating from the same cause, viz. the predominance of the negative fluid, occasionally aggravated, by the heat arising from its union with the positive, either from the air or improper diet.

Immediately preceding thunder storms, if the ground is very dry, the positive fluid will sometimes charge the air to the very surface of the earth. Therefore when a discharge takes place, that is, when the two fluids unite, the positive will sometimes pass from the air into the earth, and in this case there is no thunder but a tremour of the earth, and sometimes the negative will pass from the earth and meet the positive in the air, when a peal of thunder is heard. In either case the fluids always pass through the nearest points of contact; and should a man be the highest object or should he be under a tree or in a house, through which the stream passes, all or part of it may be transmitted through his body, when he is thrown down or struck dead, merely by the quantity of the fluid, having no signs of fire or violence about him, This is different from being killed with what is called the *thunder bolt:* in cases of death by the thunder-bolt when small holes or marks of burning are found in and about the body, the person was charged with the one fluid when the other approached, and their union took place in his body. The tendency to putrescency in bodies killed with lightning is well known to be very great; and it is also found that the flesh of animals, as fowls, killed for the table by a discharge from a Leyden battery, is rendered very tender: the divellent effects of the Samiel are still more virulent. See page 521.

But independently of this extreme case, as a change in the aerial electricity either as to the opposite fluids or their quantity, always precedes and accompanies a change of weather, we must expect that the animal economy will be sensibly affected by these changes.. Hence on those occasions we find almost every person has some ache or pain, lassitude, or dulness to complain of. And if we look at the animal creation, for they are all more sensible of it than man, we shall find the whole in commotion: the birds cease their warbling, and seek the innermost coverts, the rooks are clamourously cawing, the herds are

lowing and restless, the sheep are seeking the sheltered side of the hill, the dogs are howling; and even fish, and the unweildy porpoise are equally disturbed in their watery element, and it is perhaps, the only time when the eel quits its muddy habitation; all feeling the disagreeable sensation of a body overcharged with electricity, and all preparing for the approaching storm.

In almost every individual, the nerves of some parts of the body, are more tender than others; and such parts will, of course, be more liable to be infected by external or different causes than others. Of whatever organs, then, the nerves may be defective, these organs will suffer the most at the approach of a storm Should the weak nerves belong to the stomach; then indigestion, or perhaps nausea may ensue; if the lungs, asthma; if the intestines, diarrhæa, or colic; if to the ligaments of the joints, rheumatism; if to the teeth, tooth ache; if to a muscle a difficulty of motion, a contraction, or spasm, or the cramp in the calf of the leg, or a lock-jaw, and sometimes the palsy; but if the brain itself be disordered, then a violent head ache, giddiness, delirium or insanity may be produced. Thus we see the same causes affect different people in various ways; but we may generally remark, that when any one is complaining of the shooting of a corn, the throbbing of a wound, the writhing pain of rheumatism, the stupidifying heaviness of the head ache or any other ache or pain, he generally ceases his com plaint soon after the rain begins to fall, for then the electricities are discharged, and his body is freed from its oppressive load.—That invalids are not equally affected previously to every storm or fall of rain, is owing to the different modes in which the earth and air are charged. When the earth is wet and the atmosphere is cold, the lower stratum of clouds is generally charged with the negative fluid; and the positive descends from the higher regions, or comes with the clouds from distant quarters; even most thunder storms are, in our climate, produced by the meeting of oppositely charged clouds, with little or no discharge from the earth; consequently the nervous sensibility we are now describing must be greatly modified.

The other diseases which we have mentioned depend on two primary causes, geological situation and climate; and they are modified by diet, exercise and cleanlines,—or, in other words, by the condition of the human frame. By geological situation is meant the tendency which the electric fluids have to arrange

themselves on hills or in wet situations. When the atmosphere is charged positive, the earth is equally charged negative; and the negative fluid arranges itself on the most elevated situations as being nearest to the positive, and here the violence of the storm is generally spent; so that in all warm climates, as in central Africa, the plains are always the most healthy when they are defended, as it is termed, by a lofty range of mountains. Such mountains are generally uninhabited, and therefore, we know nothing of the dreadful effect of such charges; but in volcanic districts and on inhabited hills near swamps or marshes and far from loftier ranges, the full effects are felt in the intermittent and remittent fevers that here prevail. As woods and trees have the same effect of collecting the electric fluid, so they are always the most dangerous places in such situations. This is well known in India, and through all that part of Asia which we have already described as volcanic; so that the fevers generally have a name that bears reference to their rise from woods or thickets as the *Jungle Fever* in India.

But where a tract is not drained of its electric fluid by adjoining hills and is withal swampy and damp; then the evaporation, especially in warm and dry weather, makes the atmosphere over that place a conductor. Now vapour rising from the earth or water is positive, and therefore in the day time the negative remains within the earth; but during the night, the air, unless dispersed by strong winds, remains moist, and then becomes highly charged negative: people remaining in such situations during the night have their nerves exhausted of the positive fluid, and are often swept off in vast numbers by intermittent and remittent fevers. There is a remarkable paper on this subject No. LIX. *Mal'aria*, of the Quarterly Review, from which it appears, that in our fenny districts of Essex, Cambridgeshire, Lincolnshire, and the East Riding of Yorkshire, these fevers mostly appear under the milder form of agues; in Holland, as was fatally experienced by our armies at Walcheren, they assume a more dreadful form; while in France and Italy, where there is greater atmospheric heat, and such tracts are situated in volcanic districts, they are still more deadly. Summer and autumn is the time when these fevers mostly prevail, for at that season the evaporation is the greatest; it is also still worse when a bog is dried up and the mud is fermenting, than when there is plenty of water; for the evaporation is greater by reason of the temperature which the mud acquires,

so that at this point of time the developement of the electric fluids is greatly accelerated.

In very hot climates, and in volcanic districts, as in the West Indies, and all the American coast in that part of the world, also in some parts of the East Indies, the sea coast is highly charged and pestilential. The British seamen often dare not venture on shore for water, &c., in the middle of the day, by reason of the excessive heat; but will go in the cool of the evening, or after sun set; when the earth's surface and atmosphere become highly charged with the negative fluid. This in some cases, especially after the body has suffered by the heat and perspiration of the day, that is, when the nerves are the most exhausted, will induce the spotted fever that often proves fatal in a few hours. Many times have the crews of our ships and fleets been thus swept away. It is this, in general, that makes warm climates so fatal to European constitutions, especially during the rainy seasons, when the same partly prevails in all situations; but in all cases, whether in cold or warm climates, strangers are always more liable to suffer than natives, or those whose bodies have become inured to the climate. On some occasions ships, riding at anchor, in the West Indies, and in the channel to Calcutta, have been infected at a distance of above 3,000 feet from the shore.

All vertical bodies, such as a house, are always charged positive at the top and negative at the bottom; so that it is a very common thing, especially in situations not very favorable to health, for all the patients in hospitals or the inhabitants of other extensive establishments, who sleep on the ground floor to be attacked by a fever of this kind, while those in the upper story remain healthy. Even in common dwellings a large, well ventilated, and less inhabited room, will mostly be positive; while an adjoining small, crowded and ill ventilated room on the same floor will be negative. Gaols or dungeons and such like places, may be considered as below the plane whereon the diurnal combination of the positive solar rays or fluid of the atmosphere and the negative fluid take place, and the inhabitants of such abodes must therefore be considered as always living in a negatively charged atmosphere; hence the origin of the malady called the gaol fever, with its numerous variations. In America, where the uncombined electricity of the earth and atmosphere, by reason of the earth's surface being chiefly of primary and volcanic formations, is incomparatively much more

abundant than in Europe; and especially in the back settlements where vegetation is luxuriant, where trees are large, and the forests extend over much of the country, the positive fluid is, as it were, entirely absorbed from the air; consequently, the inhabitants, living continually in a negatively charged atmosphere, have the same cadaverous appearance as those who inhabit the most unwholesome marshes of Europe, or such as have just escaped from a dungeon. Even animals, in that part of the world, shew by their stunted growth, when compared with those of the old continent, that its atmosphere is uncongenial to life.

That the indigent often fall victims to the typhus, while the wealthy in the same town escape, is owing to the following circumstances. The poor neglect to ventilate their houses, and are unable to maintain sufficient fires which would alone ventilate them, and which is one of the best rectifiers of an unwholesome, negative atmosphere. Want of cleanliness is also a powerful promoter of this disease, for the absorbents cleanse the skin, but introduce the filth into the system; yet, the chief cause, it must be confessed, is the want of sufficient nourishment. From the stomach are the nerves supplied with the positive fluid; but the nerves of the poor in times of scarcity have often, for a long continuance, but a very scanty supply, when at length the typhus comes under the name of an epidemic, and thins their numbers.

Previously to an earthquake, the typhus has been known to prevail over a great part of the globe at the same time. And as we have shewn that vegetables charged with the negative fluid fade and die, so, during the time this fever raged, even vegetation, both in grass and trees, has in certain places been suspended under its pestilential influence. The time when the plague makes the greatest ravages in Constantinople, is when a N. E. wind prevails, that is, when the earth is charging the damp air from the Black sea negatively, and which is rushing southward to join the positive air of some distant, perhaps African, region. And in this same city, "a frightful storm has been known to put a sudden stop to the contagion." Asia Minor is almost the peculiar region of earthquakes, and here the plague prevails more than in any other part of the world. Also a great many of the plagues recorded in history have been accompanied by earthquakes; and the commencement of most of them has been ascribed to the noxious vapours arising from

some swamp or marsh, as from the Serbonian Bog in the time of Justinian, when the plague almost desolated a great part of the Roman empire, and its accompanying earthquake buried the inhabitants of Antioch and other cities in that part of the world beneath the ruins of their houses. The plague, therefore, we consider as originating from the earth's surface being ready charged for an earthquake or storm, but receiving its peculiar form from the climate, and mode of life of the inhabitants of those regions.

Physicians, in all ages, have taken great pains to trace the origin of the plague and other diseases, mentioned in this article, to the winds: and no wonder, for being ignorant of the true cause, it was to be expected that an accompanying effect would call their attention. Their is a paper on this subject in the New Monthly Magazine for May 1824. Now the earth being highly charged with the negative electric fluid is both the cause of the malady and of the wind. Volcanic regions, independent of the charges previously to earthquakes or eruptions, are always less or more charged at certain seasons of the year: and these charge the air negative, when it causes a wind towards a more southerly positive region, so that wherever this wind blows it must be pestilential; and as it always blows from the same cause, it must be always in the same direction: so that certain diseases might very justly be ascribed to certain winds. The author of the above paper cites the following passage from Frommond. "The inhabitants" of the Azores when the south wind blows "then go about as melancholy as if some misfortune had befallen them. The little children stay within doors quite dull: none of them are to be seen running about and playing in the streets. But as soon as the north wind again begins to blow, all is once more life and bustle." Now these islands, which are volcanic, are so situated, that they can seldom have a south wind which is not occasioned by the earth's electric charge attracting the positive air.—It has likewise always been remarked that these fevers have been dispersed by stronger contrary winds or storms: for in these the electric fluids are discharged.

Great pains have also been taken to find noxious effluvia in the exhalations from those marshes where the fevers prevail, but this has always eluded detection. Now, though we ascribe no pestilential effect to any thing else in these effluvia than their electric charge; yet we have sufficient data for the inference

that something more may be exhaled than mere aqueous particles. Every one must have noticed the disagreeable stench arising from house drains, previously to rain or storms, especially when the barometer is low in a raw, frosty morning; at which time we consider the earth as charged negative. And as the negative fluid in the galvanic apparatus evolves hydrogen gas from water, we may conclude that the inflammable gases, such as sulphuretted, phosphuretted and carburetted hydrogen, may be evolved from common sewers, and stagnant marshes. It is somewhere recorded that when the Yellow Fever raged very furiously in an insulated district in America, every evening, during that period, a blue mist was observed to hover over the devoted place. This mist was probably carburetted hydrogen gas evolved by the charged state of the earth. Such blue mists have often been seen in Asia, and are always considered as harbingers of the plague.

It now remains that we offer some hints by way of prevention. Rome has become much more unhealthy, since the cutting down some woods situated between it and some marshes; and other places have had their salubrity improved by the removing of trees, walls, and towers. Now any eminence, whether hill, tree, or wall, situated near a swamp, must attract the electric fluid and retain it like the prime conductor of a machine or a Leyden Battery; and the summit or immediate neighbourhood must be rendered pestilential. Should such eminence be between the city and swamp, at a sufficient distance from the former, it must escape; for, the charge is not like that of a volcanic district sufficient to cause a wind: but should the eminence be in the city, then the nucleus of the pestilence is among the inhabitants. Independent of this, if the town contains much stagnant water, in sewers, ponds, &c., as is shamefully the case in Rome, and most of the towns in the United States of North America, where all concur in the remark, that the yellow fever is never fatal till their filthy pools of stagnant water, have a green scum over them, each house must be charged with the electric fluid and with death.

The fenny districts in England are much less insalubrious than formerly; and they are principally rendered so by draining, which is the most effectual and the only radical cure. Whatever removes the stagnant waters of a district, promotes the health of its inhabitants; on the contrary, whatever tends to increase stagnant waters, or the surface of inland water, must

increase the humidity of the atmosphere, and consequently diminish the salubrity of the place: a consideration too much lost sight of by the promoters of canals in opposition to tram-ways. In short, whatever advantage may accrue from a canal in a commercial point of view, it may, with respect to the health of the inhabitants, be pronounced a curse to the country. The best personal preservatives against the ill effects of a marshy district, or of wet springs and autumns, which are in all districts frequently rife with agues and fevers, are, along with a substantial and nourishing diet, and a good fire within doors, to avoid the evening dews, especially when there is no wind, and to use warm clothing; that is, such as is formed of non-conducting substances, as wool—or what is still better, silk; for this prevents the nerves from being exhausted of their positive fluid.

7. THEORY OF PHYSIC.

THE efficacy of Medicine depends upon its chemical affinities or electric energies. The student of Nature may consider all that has been said of the simple or elementary substances, and their combinations, whether as mineral, vegetable, or animal substances, as a description of the *Materia Medica*. Let him consider for a moment, what various effects these elements, either alone or compounded, must have when taken into the stomach, or even when applied externally. Then let him remember what a complicated machine the human frame is,—what a number of bones, what a multitude of ligaments, what hundreds of glands and muscles, what thousands of arteries and veins, what myriads of nutrients and absorbents; and what a wonderful apparatus for producing heat by the blowing of the bellows in the lungs, and the lightning of the nerves,—and he will be sensible, what an extensive, what a beautiful, what a sublime and wonderful study is that of *Physic*.

As the disorders, to which the animal machine is subject, are infinite; so we may say that the medicines which may be compounded from the elementary substances, and which nature has already compounded from them, are likewise infinite in their effects; and it is found that there is no part of the body but may be reached and have its economy altered by their agency. The healing art may be arranged under three general heads. 1. Finding the seat and nature of the disease. 2. Deter-

mining the one principal medicine for curing that disease. 3. The best manner of exhibiting that medicine, so that its force may be directed to the morbid part, with the least injury to the sound parts.

The difficulties of the *first* rule are these. All diseases depend upon the nerves being injured, or not duly performing their office; and as the nervous system is by sympathy but one organ, therefore, if the nerves of one part suffer, the whole must be affected; and the most skilful physician will sometimes be at a loss to determine which is the part originally suffering. The difficulties under the *second* rule are these: when he has discovered the seat and nature of the disease, he has to find out the general state of his patient's constitution and his temperament; for he who would prescribe exactly the same medicine for every patient who is troubled with the same complaint, would be little better than the empyric, who proposes to cure all diseases with one nostrum. The difficulties under the *third* rule are many and extensive. For as medicine is conveyed into the system by the stomach and circulation, how is it to reach the liver, for instance, without its equally affecting all parts of the body which may be sound? The skilful physician, therefore, considers what are the substances secreted by the liver, and he exhibits such medicines as will not be secreted by the other organs, or will have as little effect on them as possible, but will have a powerful effect when they arrive at that viscus.

All medicine may be divided into two kinds: the heating or stimulating, and the cooling or sedative; also, diseases may be arranged under two heads,—subirritation and superirritation; that is, where the organs are in such a state as not to combine a sufficiency of the electric fluids to maintain the vital fire; and where, on the contrary, it is so great as to endanger the delicate fibres and produce inflammation. In the latter case, the patient is relieved by blood-letting, so as to diminish the quantity of the red particles in the blood, and of course the supply of oxygen; and by either evacuating the stomach, refraining from food, or using that with medicine of the cooling kind, that both sources of the electric fluids may be diminished. Should the inflammation be in a limb, then bleeding at the artery which supplies that limb is used; but this cannot be done in every case; and in all it requires too much skill in surgery for every practitioner.

The diseases of subirritation are of more difficult cure; since it is much easier to diminish the vital fire than to increase it, especially where the stimulus is wanted in one particular part of the body. For as the malady proceeds from the nerves not conducting a sufficient supply of the positive electric fluid to the suffering part, medicine of the heating kind cannot be exhibited so as to sufficiently raise the temperature of that part, without irritating the sound part of the body to a fever. Hence the utility of galvanism, or of charging the supplying nerve of the languid part, with the positive fluid from an electro-apparatus. But besides the judgment of the physician necessary to determine when and to what extent this should be done, it will in some cases defy the skill of the most able surgeon to reach the nerve, and therefore galvanism can never be introduced into general practice.

So great was the enthusiasm at one time among the cultivators of the science of electricity, that very able men asserted that there is no disease incident to the human frame, but may be removed, or at least its violence greatly mitigated by the external application of electricity. However the foregoing pages will shew the fallacy of such assertions: for, they demonstrate that if the animal machine is moved by electricity, it is not by its being poured upon the body at random. But the negative enters the blood by the lungs, while the positive enters by the food of the stomach. The former is distributed through the system by the arteries conveying the blood, and the latter by the nerves; and they are combined by the inscruitable laws of life at a precise point pre-ordained by the unerring skill of the all-wise CREATOR. Whereas, electricity applied from a machine charges all the muscles, bones, arteries, and nerves promiscuously; and where the nerves and muscles of a vessel merely wanted their electric energies rousing, so as to hasten the secretion, the fluids are made to combine in the coats of the vessels at the hazard of their dissolution. In rheumatic complaints, as the lumbago for instance, the external application of electricity has been known to cause suppuration about the loins, which is attended with almost sure death. The cause of rheumatism is the nerves being in such a state as not to supply the absorbents, which consequently do not perform their office; now should these delicate vessels thus distended with lymph, perhaps nearly in a stagnant state, be exposed to an overshock

of electricity, the worst consequences may ensue. However it cannot be denied that even this random mode of application has, in some cases, been attended with the greatest benefit. The progress of fluids along capillary tubes, and such are the absorbents, nutrients, and glandular vessels, is generally accelerated by their being charged with electricity; consequently, it may not only assist and stimulate the nervous system, but evacuate the glands and absorbents.

The general mode of application is to place the patient on an insulated stool, charge him with the positive fluid, and draw sparks from the diseased part with a wooden point; when, the operator standing on the ground, or holding the negative chain, and of course completing the electric circuit, a small portion of the fluids will be united at the point or place affected.

8. THE SENSES.

The heart is generally spoken of as the seat of life, on account of its being the organ that causes the circulation of the blood, which in common language is called the stream of life. But as all muscular contractions depend upon the office of the nerves, which contractions give motion to the heart, it is evident that as the brain is the source of action, so must it also be the prime residence of life.

Now as muscular action ceases as soon as the electric power of the brain is destroyed, and for any thing we shall ever know to the contrary, life also ceases or takes its flight at the same time, the only conclusion we can draw, is, that the intangible unknown principle we call *Life*, not only resides in the brain, but has its seat in or is inseparable from the electric fluid. That life does not constitute the capability of the nerves for conveying the electric fluid, is evident from the effect that galvanism has upon recently killed animals; for it will produce all the muscular contractions necessary for corporal motion; yet, for want of the directing power of the Will, or the laws of life, no determined motion of a limb or body can be produced.

The nerves are continually in a charged state, conveying the electric fluid to all parts of the body where the circulation or action of life is going on; and each larger chord is composed of a number of smaller ones, and bedewed with the fine unctuous fluid of the dura mater. And so delicate is the structure, that whatever external impression is made on them, whether by sim-

ple compressure, destruction of their contexture or chemical affinity, must effect the state of the whole nervous system; and as life resides in this system, it must be variously affected in its seat. When the brain is exposed by the removal of part of the skull, a small pressure upon it, as with a handkerchief, causes dimness of sight, and drowsiness increasing to apoplexy. And when the person falls asleep, the brain shrinks and subsides; but the moment he awakes, a tide of blood is seen rushing through the vessels and swelling the brain. When the blood flows rapidly in delirium and inflammation of the brain, the patient is deprived of sleep, unless the current is retarded by opium or bleeding. Retard, therefore, the flow of blood to the brain and you induce sleep; quicken it, and you drive it away.

The sentient power is situated in the nerves, and its acuteness is perhaps greatly owing to their delicacy of texture; but in the brain is the great sensorium, whither all the impressions on the nerves, as produced by the five senses, are conducted. That it resides in the brain and is not equally distributed over all the nervous system, we think one circumstance sufficient to prove, viz. a man who has lost his leg will frequently complain of a pain in his toes, which would not have been the case had any of the sensorium ever been therein resident.

The nerves terminate all over the body, immediately beneath the epidermis, in small papillæ, which exude the unctuous fluid existing between the two coats, and with which the papillæ are continually moistened. These papillæ are by far the thickest set in the seat of the senses, viz. at the finger ends, on the tongue, in the internal cavities and sinuses of the nose; though in the ear they give place to a finer ramification; and in the eye the retina is a complete and substantial film of the most minute nervous chords, crossing each other as a net work in every direction.

TOUCH. The sense of *touch* is the effect produced on the brain by simple compressure of the nerves, without reference to the chemical quality of the object. It is consequently the most obtuse of all our senses; yet perhaps is more capable of improvement than any of them, since we are almost every day amused with the tangent feats of those who have the misfortune to want the sense of sight. In short, its use may be considered as in a great measure superseded by that of the other senses; and it is, therefore, obtuse merely from want of cultivation. The general sense of *feeling* may be considered as that of touch

extended over the whole system; and seems designed by the Great Contriver, as a centinel to give notice of any danger. It depends on the impression and effect produced on the nervous system, whether by injury of their medullary substance, compression or chemical affinity. The sensations of pleasure or pain depend upon the mind or animal life whose nature it is not our intention to investigate.

It has been asserted that the *caste* among the Hindoos, condemned to manufactures, have a wonderful *tact*; and as all generations continue at exactly the same trade, so this superiority of the finger ends is transmitted from father to son: hence it has been supposed that in certain arts they will always excel the Europeans.

TASTE. *Taste* and *smell* depend entirely upon the electric energies of the object. When a dry substance is placed upon the tongue, the tongue being dry also, we do not feel the sensation which we call taste. But let a little of it be dissolved in the saliva, so as it may reach and mix with the fluid exuded by the papillæ of the nerves, and an electric developement takes place, and produces the peculiar effect on the great sensorium. Now as we have repeatedly shewn, that no two substances compounded of different elements or different proportions of the same elements can present the same chemical affinities; so they cannot produce the same effect upon the nerves; and consequently cannot have the same taste. Hence that wonderful variety, in this respect, in the productions of nature, and that endless variation of flavour imparted and produced by art.

SMELL. The passage from the nostrils to the back part of the mouth or larynx is not made in the most direct line or regular curve. But just beyond the aperture of the nostrils are two cavities, one to each nostril, which gradually expand till at last they unite in one: each of these cavities has three sinuses. The uppermost one extends almost under the eye-brows; the middle one is a kind of sieve-like bone or spongy cavity; and the lowest takes the direction of the upper jaw. The whole is lined with a membrane called the pituitary membrane, which is of a spongy nature, and composed of vessels, nerves, and glands. From the glands is secreted the mucus, and the nerves terminating in the papillæ are moistened with their own fluid. Into these cavities, then, is the air inhaled; and the membrane separates the foreign ingredients from it, viz. the particles of volatile oil, or whatever else is dissolved small

enough to be carried on the wind. As this membrane is always supplied with those two fluids, and farther moistened by the breath; so these particles are immediately diluted; and the electric chain between the nerves and their inherent fluids is instantly completed, when the sensation which we call *smell* is produced.

Whatever sense other animals possess in a higher degree of perfection than man, it is always found that the proportion of nerves in the seat of that sense is equally greater. But what is very remarkable, and which must depend upon a contexture far too fine for us ever to examine, the senses are often not general. Thus: the dog has a wonderful sense of smell with respect to certain scents or odours, for which man has little or none; while, on the contrary, we cannot perceive that the fragrance of flowers, so very grateful to man, has any effect on the olfactory nerves of the dog.

HEARING. This sense depends on certain impulses of the air producing certain contractions in the fibres of the radiated muscle situated at the centre of the membranum tympani, which, by vibrating, gives motion to the wonderful and curious mechanism included in the drum of the ear, and by this means communicates corresponding impulses to the air contained therein; and these impulses produce certain impressions on the auditory nerves placed in different parts of the upper portion of the internal ear, as already stated, Chap. VII. s. 7. It is supposed by some, that the air in the drum or internal part of the ear, is acted upon like that contained in the hollow of a drum or violin; and that the Eustachian tube is to the ear what the vent holes are to these instruments, which let out the imprisoned and affected air, and without which it is well known they will not emit the proper sound. It is certain, that when the Eustachian tube is obstructed, whether by natural defect at birth, by cold, or accident, the person is deaf. Hence Sir Ashly Cooper discovered a method of restoring the sense of hearing, by making a small hole through the membranum tympani to the external air. Where the base of the stapes covers the fenestra ovalis, it vibrates upon it like the key of a flute; so that the air in this part of the ear, viz. the passages leading up to the brain, is also acted on in the same manner: the vent-hole being the fenestra rotunda. The whole of the internal ear is moistened with the fluid of the nerves; and indeed this fluid almost fills the upper part; and as usual is in contact with

the nerves, wherever their numberless branches are spread. In the vestibule, on the entrance to which the stapes plays, this fluid is contained in two little bags, whereon a part of the nerves is spread. When the nervous fluid is wanting, the sense of hearing is also wanting.

The above is but a very imperfect description of the organs of the sense of hearing; but, in short, they are too curious, and their use is too imperfectly understood to be adequately described. One circumstance is very remarkable in these organs, viz. they are all as large and as perfectly developed in the infant as in the adult.

SEEING. The sense of seeing depends on the rays of light, which emanate from bodies in all directions, and which enter the eye; and, being therein made to converge by the eye's peculiar structure, paint an image on the retina or optic nerve. The sensation caused by this image must depend upon two circumstances, viz. the *intensity* of the rays, which must depend upon the magnitude of the abject, also its distance, as explained Chap. VIII. sec. 8; and its *colour*, which depends on the chemical properties of light.

The manner in which light produces its peculiar sensation on the nerves, seems owing to the contrivance of the posterior part of the choroides, called the *tapetum*. The external covering of this coat is in man of a dark brown or purple colour; but its colour is different in different animals. In the ox, it is green; in the dog, grey; in cats and owls, it is of a whitish colour. Upon it is the retina or nervous film. The rays of light therefore penetrate the retina, but are variously affected when they arrive at the tapetum: some being absorbed while others are reflected. But the reflected rays seem to be what principally produce vision; for, by being reflected, or by not entering the tapetum, they are entangled in the nerves, and thus produce their peculiar effect.

Now we suppose the colouring matter of the tapetum to be oxygen; consequently, in man these reflected rays will be those of the indigo side of the spectrum; and as they are less powerful than those of the calorific side, therefore, light does not make that lively impression on the optic nerve of man, which it does on that of other animals whose tapetum is not of so deep a colour: hence man sees worse with a small portion of light than any other animal. On the contrary, the tapetum of cats

and owls contains the least oxygen (its colour being whitish), and for that reason it reflects the calorific rays upon the optic nerve; which being the most powerful create the greatest sensation; and these animals can therefore see with very few rays of light, even so few, that man would call it total darkness; but by reason of the overpowering sensation, they are comparatively blind in the sun-shine. In the ox, the tapetum, being green, reflects the colour of the grass his chief food. But indeed we shall ever find that the colour of this membrane is always edapted exactly to the creature's peculiar mode of life. Man, that he might rest by night, is compelled to it, by the deep colour of his tapetum, and consequent darkness. Dogs, cats, and owls are predatory animals, and are enabled to seek their food by night, or when their prey is tempted from its lurking places, by the absence of man its greatest foe.

But as light is identical with the cause of chemical affinity; so each ray, as seen on the spectrum, must produce its peculiar effect on the moisture or positive electricity of the nerves: hence the sensation of colour, and its infinite variety in the works of Nature, the source of so much rational enjoyment to man.

9. THE WILL.

It would seem that Life holds its right to reside in the body on condition of performing certain offices, viz. regulating the electricity of the brain, and dealing it out to the different parts of the body where it is needed for muscular action. Now the office of distributing this electric fluid, so as to actuate the muscles, comprehends two distinct agencies, which have their own respective spheres of action; the *one* is constant, the other is casual. The constant muscular contractions are those which keep the vital organs, viz. the heart and lungs, in action; which action cannot for a moment be suspended without Life hazarding its possession of the body. But the other agency consists in casual contractions of the remaining muscles; and they depend upon certain determinations of that attribute of Life which we call *Will*. Therefore what we are to understand by this word *Will*, is the power which Life possesses of distributing the electric fluid so as to cause the contraction of certain muscles, while others remain at rest.

Now *Will*, considered in the abstract, belongs equally to all

animals; for they all, as far as we know, possess the power of performing certain actions in preference to others. However this *elective* power seems stronger in some than in others. In some it amounts to the semblance of reason, when we call it *instinct*. But on the whole, it is always furnishing proofs that we know nothing at all of the real nature of Life.

Notwithstanding our ignorance in this respect, we yet presume to know something of the offices of life; and as these are discharged, not only with perishable instruments, but also with such as are in continual need of repair, and that in proportion to their use, it is very plain that the more they are used, the greater will be the wear and expenditure of the repairing materials. However life has one very important privilege granted, viz. when her instruments are very much worn, she can suspend the functions of one office, till they are repaired by the operation of the other. This cessation we call *sleep*.

Now that her instruments are not equally worn during this suspension is sufficiently proved by one circumstance, viz. carbonic acid and aqueous vapour are the chief substances produced by such use and wear; and we find less of these evolved during sleep than at any other time. And as the instruments must be more worn when she discharges both offices with the greatest despatch and utmost power; so we find that upon those occasions, her calls for the repairing materials are the most urgent; and the cessation of the one office is the most complete, and is continued for the longest time. On the other hand, when the office of volition is but sparingly executed, her instruments are too powerful;—she has more for their repair than she can dispose of,—her cessation of it is therefore never complete and but short, and her instruments are apt to be almost useless or put out of repair, by being too much clogged with the repairing material.

But this is not the only time when she has more of the repairing material than she can conveniently or possibly dispense with. Her supply is from the stomach; and this storehouse is sometimes so immoderately crammed, as in the case of alcohol, that such an overwhelming flood is sent to the brain, as shakes life on her throne; so that her instruments are like overfed horses, that despise the rein, throw their rider, and hurry on to their own destruction. On such occasions, she either uses them without any particular aim, or finds them, under such circumstances, so unmanageable, that she is either driven from

or compelled to desert the functions of one office, and sometimes of both. That she is now expelled from her seat by the most extreme violence is very evident from this circumstance, viz. when she is made to suspend her office by a violent concussion of the brain, she conducts herself exactly in the same manner, as when she is made to suspend it by an overdose of alcohol.

Besides, life is variously affected by certain gusts called passions; which, when gentle, make her discharge the functions of both offices with greater alacrity; but when violent, they sometimes cause a suspension of both. However, as they are partly under the control of a certain power, viz. the *soul* or its emanation, *reason*, which is or ought to be superior to *will*, but which we know no more about than that it really exists, and exerts a controlling influence, we shall at present say no more upon this subject, than that it seems to be beyond our reach.

10. CONCLUSION.

We have now arrived at the conclusion of what may be considered an outline of the Natural History of Matter; and hope that we have said enough to enable the young philosopher to interpret the book of Nature. We might have ascended from vegetable and animal life, to the soul, or its attribute and emanation, mind and reason; thence to the attributes of the Supreme Being. But here we find no connection;—there is no chain of induction to lead us from matter to mind; and we might as well attempt to create another planet like that we inhabit, as to explain how man moves and acts without the intervention of life and mind; or to say how that mind could possibly result from any principles inherent in matter. Though we have all along shewn the electricities to be the instruments with which the material world is put in motion; yet, that they could not build the beautiful frame of Nature by their own directions, must be obvious to every one; since, evident marks of contrivance, and these bearing the stamp of infinite wisdom, meet us at every turn; so that nothing seems more plain than this conclusion, that a Being infinite in power, wisdom and benevolence must be the Author of Nature.

However, there is no need to adduce arguments to prove that a Supreme Being created and still upholds the universe,—there is no one now-a-days who would not consider it a mark of sot-

this stupidity to deny the fact; but there are many who are clamourous for more tangible proofs of his interference in human affairs, and of the responsibility of man in a future state. Could they be convinced of this, or rather durst they allow themselves to admit the fact, they would need no persuasives to induce them to catch at every plausible record of a revelation that has the character of proceeding from such a Being; and then, it is very certain, that they would want no new arguments to convince them that such a revelation we already possess, which bears on whatever side we view it, the most evident marks of a divine original.

Now the material world is not the source whence we are to draw direct arguments to prove the need of a revelation, or that one has in reality been given. Those which it furnishes are rather of the negative kind, and are such as follows: we cannot by any means, while viewing the mineral kingdom, find any arguments to prove the possibility, or even the actual existence of either the vegetable or animal kingdom. The most acute materialist cannot say how soil, water, air and heat can assume the form and functions of even a mushroom, much less the energetic motion of the race-horse or the reasoning faculty of the philosopher. And should we allow him one step farther, and shew him an acorn or an egg; by what arguments, from their appearance, can he prove that the one will produce a tree and the other a bird? Neither is he any better if we give him the carcase of the race-horse or the body of the philosopher to dissect; or all the aids of chemical analysis to investigate the composition of the egg, the acorn or the mushroom. If therefore we can find no arguments in the mineral kingdom, for the existence of the vegetable or animal kingdom; we should not wonder if no circumstance of the three afford any direct proof of the need of a revelation, or tangible evidence that the same intelligent Author of the universe, together with the administration of the affairs of Nature, takes cognizance also of the motives and actions of men.

Again, we know that vegetable life imposes new laws on the energies of matter; we know that animal life is more perfect than vegetable; we know also that man is endowed with reason;—but, we do not know how vegetable life is connected with matter, we know not how animal life excels the vegetable, neither do we know what the human intellect is. Animal life may be a something added to the vegetable, and intellect, may

be but another step in the same scale of perfection; but they may be altogether distinct. If therefore we are ignorant of these,—is it to be wondered at, if we have no manifest demonstration of the manner in which the supreme, eternal Spirit holds communion with the soul of man? All are equally his workmanship; and since the material part of the body is acted on by the principle called Life; and this is again partly under the dominion of reason;—may not there be an intimacy of communication between the spiritual part of man, and the supreme Spirit, similar to that between reason and life, or between both and matter; though the peculiar mode of this intimacy be still placed beyond the insurmountable barrier fixed between us and a manifest demonstration?

Revelation teaches us that the reasoning faculty of man depends upon a soul or spirit, whose nature is nearly allied to the Divinity or the Supreme Spirit, and which like it is immortal. It has also made certain other declarations respecting this soul, which it has not made respecting the life of animals and vegetables. Yet, since it has left us entirely ignorant of the latter, and we cannot by our reasoning faculties search out their nature;—why should we pretend to cavil at what is revealed of the former, because we imagine there are many circumstances not revealed which we are unable to search out by reason? And if this is the case, what foundation have we for the assertion, that the connection between vegetable and animal life and mere matter, is less beyond the reach of our understanding than the union of an immortal spirit with a perishable body, or the medium through which the Deity holds communion with that spirit? The manner in which Deity became invested with man's nature; the mode in which the Deity was thereby reconciled to offending man; the mysterious way in which the dead shall be raised; and the final accomplishment of the eternal acceptation of virtue and reprobation of vice, are all, it is true, entirely beyond the reach of our comprehension, though perhaps not equally so; but since we know nothing of the distance of any of them, it is consequently an absurdity to say that any one of these deep questions in Theology is more incomprehensible or mysterious than the nature of the meanest plant.

It may therefore be asked—what advantages, in a religious point of view, do we derive from the study of the philosophy of Naturė? to which it may be answered—many. But they depend upon our first knowing that a revelation has been given,

and on our being thoroughly acquainted with it; for then, and not till then, we read the same supreme intelligent Author in his works that his word declares. And it is a matter of no small triumph, and the utmost we can expect, if we prove, as most certainly may be proved, that from all the discoveries in Natural Philosophy which have been made since this revelation was given, not one circumstance can be adduced as affording solid foundation for an argument that the one contradicts the other. It may even be farther safely asserted, that by whatever spirit the Holy Scriptures were dictated, that spirit was acquainted with the whole, and apparently much more than has been brought to light by the reasoning faculty of man; so that, it must at least have one attribute that we suppose to belong to no other than the Supreme Spirit, namely, infinite Wisdom.

Besides, as a great part of the intellectual enjoyment of man consists in contemplating the wisdom, power, and goodness of his Creator; it is no small advantage to have the sphere of this contemplation enlarged, as it certainly is, by the science of electro-chemistry. For, from knowing the utmost extent of the capabilities of mere matter in the mineral, vegetable, and animal kingdoms, he is more perfectly assured of the wide distinction between matter and mind. He is, also, enabled to trace the divine skill through all the phenomena of Nature to the origin of this planet; or, commencing with its origin, he can contemplate the different stages of matter from its first emission from the hand of its Creator, floating forth a mere ocean of uncompounded elementary substances, without form and void and with darkness on the face of the deep, till the Almighty Word went forth, as the all pervading Spirit brooded over the immeasurable abyss, and said, "Let there be light" and these hitherto inert elements became one boundless blaze; when this fair frame of Nature, arose in radiant beauty from the chaos.

He can now, likewise, with more precision define the boundaries between what is known and what is not known; between what he may reasonably expect to arrive at a perfect knowledge of, and what he must ever despair of fully comprehending. He sees a wide field wherein future discoveries may be made by his own unaided powers of reason; and he beholds unbounded regions full of what he has a most ardent desire to become acquainted with, but what he feels convinced that he

cannot, except by direct revelation from the Author of Nature. His conviction that something has already been revealed is every day receiving additional strength; but at the same time he is convinced that as yet he knows but in part; however, he is forcibly impressed with this important conclusion, that every thing he sees is the result of contrivance tending to some great, but as yet incomprehensible design; and that the self-same Being which imposed these laws on matter, with such visible marks of contrivance, is no other than that revealed in the pages of the Old and New Testament, and therein represented as clothed with the attributes of infinite power, wisdom, and benevolence.

Nothing, in short, seems more plain than this inference, that the Word of God and the Works of Nature, as now displayed by the electro-chemical principles, are but comments on each other. For this new doctrine, if such it may be called, teaches that all matter is elaborated by the electric principles; vegetable life is carried on by new laws imposed upon them, animal life is still resident in them, and undoubtedly the soul also has its seat in them. The electric fluids are identical with light. And the Divine Word always represents the Deity, whether as the Shechinah or Angel of the Covenant in the Old Testament, his transfiguration on Mount Tabor, or manifestation to St. Paul in the New, or the immediate presence of the Trinity in the Apocalypse to be in light ineffable. It is evident, therefore, that the more we understand of the secret laws of Nature, the better foundation we have for this conclusion, viz. that the same intelligent Power which planned and created the Universe, dictated also those scriptures which the better part of mankind, that have known them, have always considered as records of the divine will. But as this supreme Intelligence dwells in light, and the human soul dwells in light,—if therefore we cannot approach to a knowledge of the latter, which resides in only so much of the electric principles as elaborate but a mere handful of matter, and we ourselves are the theatre of the action:—how can we possibly reach to a knowledge of that Spirit which resides in, and guides the electric energies that elaborate the matter of the whole universe!!

INDEX.

With the *Greek* and *Latin* derivations of most of the technical terms made use of in this work.

N. B. The derivation is only given when it elucidates the meaning of the word.

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J

THE END.

W. Robinson, Printer, Stockton-upon-Tees.